SATELLITE OCEANOGRAPHY

HEARING

BEFORE THE

SUBCOMMITTEE ON OCEANOGRAPHY
AND THE GREAT LAKES

OF THE

COMMITTEE ON
MERCHANT MARINE AND FISHERIES
HOUSE OF REPRESENTATIVES

ONE HUNDRED FIRST CONGRESS

FIRST SESSION

INSIGHTS INTO THE STATUS OF AMERICAN TECHNOLOGY AND CAPABILITIES IN SATELLITE OCEANOGRAPHY

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SATELLITE OCEANOGRAPHY

THURSDAY, APRIL 27, 1989

House of Representatives,
Subcommittee on Oceanography and Great Lakes,
Committee on Merchant Marine and Fisheries,
Washington, DC.

The subcommittee met, pursuant to notice, at 2:03 p.m., in Room 1336, Longworth House Office Building, the Hon. Dennis M. Hertel (chairman of the subcommittee) presiding.

Members present: Representatives Hertel, Goss, Hughes, and Brennan.

Staff present: Ray O'Malley, Brian O'Malley, Bill Ashworth, Dan Ashe, Judy Wells, Joan Bondareff, Lisa Pittman, Larry Flick, Charlie Moore, Tom Kitsos, and Ed Welch.

Mr. **Hertel.** We will call the meeting to order this afternoon.

OPENING STATEMENT OF HON. DENNIS M. HERTEL, A U.S. REPRESENTATIVE FROM MICHIGAN, AND CHAIRMAN, SUBCOMMITTEE ON OCEANOGRAPHY AND THE GREAT LAKES

Mr. **Hertel.** For the past two decades, oceans and space have represented mankind's last frontier. Both represent environments which have pressed the technological capacities of mankind and yielded a vast wealth of information.

Satellite technology has the potential of greatly revolutionizing oceanographic research capabilities by improving our ability to observe critical earth processes from space.

Satellite remote sensing can open windows to examine seasonal changes in the biological productivity of coastal water caused by certain pollutants or red tides, and monitor global climate changes, surface winds, and undersea currents.

Despite the proven power of satellite imagery in ocean science, satellite development and planned launches have decreased dramatically in recent years.

Important oceanographic missions have been cancelled or postponed, not as a result of technical difficulty, but because of constrained resources.

Current U.S. satellite capability to support oceanography is very limited. Our Nation has failed to build or fly crucial instrumentation vital for both our national security and economic well-being. In the absence of our domestic capability, our scientists are increasingly reliant on satellite sensing from other nations.

Our witnesses today will provide us insights into the status of American technology and capabilities in satellite oceanography. I hope they will also outline a vision of the future upon which we can embark on an expedient and affordable program to give our Nation vital capabilities in this area.

Mr. HERTEL. Mr. Goss, do you have an opening statement?

Mr. GOSS. Mr. Chairman, thank you very much. My interest, as you know, as I expressed this morning—I understand we are going to illuminate as we go along in the testimony today, and I will wait my opportunity until afterwards. Thank you very much.

Mr. HERTEL. Thank you.

Our witness panel today will consist of Mr. Thomas Pyke, Jr., Assistant Administrator, Satellite and Information Services, NOAA; Dr. Shelby Tilford, Director, Earth Science and Applications Division, Office of Space, Science and Applications, National Aeronautic and Space Administration; Rear Admiral Richard Pittenger, Oceanographer of the Navy; Mr. Robert Corell, Assistant Director, Geological Sciences, National Science Foundation; and Dr. James Baker, President, Joint Oceanographic Institutions, Incorporated.

We would appreciate it if we could put your statements in the record, and if you could tell us exactly what you really think. We will begin with Mr. Pyke.

STATEMENTS OF A PANEL, CONSISTING OF THOMAS N. PYKE, JR., ASSISTANT ADMINISTRATOR, SATELLITE AND INFORMATION SERVICES, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, U.S. DEPARTMENT OF COMMERCE; DR. SHELBY G. TILFORD, DIRECTOR, EARTH SCIENCE AND APPLICATIONS DIVISION, OFFICE OF SPACE, SCIENCE AND APPLICATIONS, NATIONAL AERONAUTIC AND SPACE ADMINISTRATION, WASHINGTON, D.C.; REAR ADMIRAL RICHARD F. PITTENGER, OCEANOGRAPHER OF THE NAVY, WASHINGTON, D.C.; DR. ROBERT W. CORELL, ASSISTANT DIRECTOR, GEOLOGICAL SCIENCES, NATIONAL SCIENCE FOUNDATION, WASHINGTON, D.C.; AND DR. JAMES BAKER, PRESIDENT, JOINT OCEANOGRAPHIC INSTITUTIONS, INCORPORATED, WASHINGTON, D.C.

Mr. PYKE. Mr. Chairman, members of the subcommittee, thank you for inviting me to discuss the role of NOAA's environmental satellites in oceanography. Since you kindly allowed that our written testimony will be submitted for the record, I will proceed to provide you with a summary of that testimony.

I intend to review, primarily, the history and the current status of oceanographic missions carried out by NOAA's operational remote-sensing spacecraft.

Today, satellite remote-sensing of the ocean utilizing weather satellites is useful to fishing, maritime shipping, and the offshore energy industry, as well as to the study of global environmental change. However, the reason for attempting oceanography from space, beginning experimentally in the late 1960's, was to improve weather forecasts.

The strength of remote-sensing satellites is that they yield environmental observations over enormous areas where no ground-based observers exist.

Polar-orbiting satellites are perfectly suited for ocean observations in that they provide global coverage twice daily. NOAA began producing weekly ocean thermal analyses in 1973, based on data from ships and from our NOAA-2 polar-orbiting satellite. This spacecraft carried an infrared radiometer, an instrument which sensed infrared, or thermal energy emitted or reflected from the Earth's surface.

These early sea surface temperature charts were distributed to NOAA's weather forecasters for use in adjusting their predictions.

In the private sector, the uses of satellite-derived sea surface temperature maps began to unfold in the mid-1970's. Entire fleets now rely on satellite-derived ocean thermal boundary charts to optimize ship routing by identifying current boundaries, and to increase fish catches by seeing the most likely areas of high nutrient concentrations.

The 1978 launch of the polar-orbiting environmental satellite known as TIROS-N was a milestone for satellite oceanography. Its new sensor, the Advanced Very High Resolution Radiometer, or AVHRR, meant new accuracies for space-based operational sea surface thermal analyses.

Distribution of sea surface temperature maps burgeoned as a greater variety of users, commercial as well as Government, operational as well as research, began receiving them on a subscription basis.

An improved version of the AVHRR instrument is flying today on board the NOAA-10 and the NOAA-11 spacecraft. It is the Nation's primary space-based observational tool for oceanographic applications, and yields overall global temperature accuracies, routinely, less than 0.7 degrees Celsius.

Future versions of this instrument will provide continuity of ocean surface observations through the 1990's. Mapping small-scale thermal features from space has proven valuable to a variety of researchers, and for real-time decision-makers. The NOAA CoastWatch program of monitoring the environmental quality of the Southeast coast grew out of efforts to identify the transport of the unprecedented North Carolina red tide of 1987-1988, which ravaged the State's shellfish and tourism industries.

NOAA satellites identified a filament of unusually warm water which broke away from the Gulf Stream and transported the devastating tropical red tide algae onto the coast.

High-resolution satellite images are now distributed to scientists who can provide alerts of any further occurrence, or impending occurrence to State and Federal response agencies.

Another application of this AVHRR instrument has been for global ice mapping. Polar region ice forecasts are issued by the Navy-NOAA Joint Ice Center two to three times weekly for defense and maritime industry requirements.

Ice often poses a safety and economic threat to the shipping industry on the Great Lakes. Here, NOAA satellites have been used to map the winter season ice advance and the ice retreat.

Aside from the notable successes of NOAA's ocean thermal analyses from space, several other marine and environmental phenomena have been studied from our satellites. However, sensor resolution, cloud cover, and the nature of the ocean surface phenomena being observe are limiting factors in observations taken by the AVHRR. Oil spills, for example, must be at least several kilometers on a side, must be thick enough to be differentiated from the uncoated water surface, and must be overflown at the correct angle relative to the sun to reflect light off the surface sheen in order to be seen.

Future remote-sensing instruments will partially overcome the cloud-cover problem. For instance, an advanced microwave sounding unit, known as the AMSU, slated to fly on our next generation of polar orbiters, beginning in about 1993, will allow us to better estimate sea ice edges through the clouds.

On a larger scale, the usefulness of satellite remote-sensing to global climate change studies was demonstrated in 1982, when that year's dramatic El Nino was first sensed by NOAA's AVHRR sensors.

In subsequent studies, data from NASA's coastal zone ocean scanner on Nimbus-7 showed all of us biological changes in areas of unusual surface warming along the Pacific coast.

Two other types of remote-sensing instruments are altimeters and scatterometers. Each of these will be flown on the European space agency's planned ERS-1 satellite, planned for launch in 1992. NOAA will receive sea level and sea-state analyses from this altimeter data, and surface wind speed and direction analyses from the scatterometer data, which we will use for global change studies.

In addition, ERS-1 will carry a synthetic aperture radar instrument. This cloud-piercing sea surface observer will provide observations of ocean wave spectra with a resolution of 25 to 30 meters.

NOAA is planning to access a limited amount of this very high-density data through participating in the use of a readout site in Alaska. In addition, NOAA and NASA are in the process of developing a memorandum of understanding with Canada for Government and private-sector use of synthetic aperture radar data from the Canadian Radarsat spacecraft, planned to be flown in the mid-1990's.

NOAA's satellites are among the Nation's prime tools for observing the global ocean, for input to weather forecasting, global change research, and commercial maritime interests. Whether it is a yachtsman eyeing the meanderings of the Gulf Stream before a race, the captain of a tuna boat looking for nutrient-rich upwelling boundaries off California, or a research oceanographer studying the vexing thermal cycles of the equatorial Pacific, NOAA's two operational polar-orbiting satellites command an olympian view of the globe and afford observations far in excess of random surface reports.

We are proud of their track record, and of their success at helping to put the "O" in NOAA from space.

Our plans call for continued operation of the polar-orbiting satellite program through the 1990's. We also plan to continue our efforts to acquire and use data from sensors flown by NASA and our international partners as we move toward the next century.

Mr. Chairman, that concludes my statement. I will be pleased to respond to any questions that you or members of the subcommittee may have.

[The statement of Mr. Pyke can be found at the end of the hearing.]

Mr. **HERTEL**. Thank you, Mr. Pyke. Next, we have Dr. Tilford.

STATEMENT OF DR. TILFORD

Dr. TILFORD. Thank you very much, Mr. Chairman. I am pleased to be here today to discuss NASA's Oceanic Processes Programs, and some of the instruments that we are developing, some of the international cooperative efforts in which we are trying to become involved.

The goal of NASA's Oceanic Processes Program is to understand, and, ultimately, to predict the role of the oceans in global change. The program objectives are to develop spaceborne techniques and evaluate their utility for observing the oceans; apply these techniques to advance our understanding of the oceans and their interaction with the rest of the global Earth system; and to assist users in the operational utilization of such techniques.

Over the past decade, we have been primarily focused on the first of these objectives, using the Seasat and the Nimbus missions, in addition to the Advanced Very High Resolution Radiometer, AVHRR, that Mr. Pyke just discussed.

Based on the successes of these measurements from space, the scientific community responded with a number of global experiments, including the World Ocean Circulation Experiment, the Tropical Ocean Global Atmosphere Program, and a Joint Ocean Flux Study, as three examples where large-scale perspectives are required.

These are supported by NSF, NOAA and NASA within the United States. They require extremely broad aerial coverage to understand what the surface characteristics of the ocean are, and how, by combining in-situ measurements from ships, and other means, that we can better understand things like the ocean circulation.

Finally, we look forward to the International Geosphere Biosphere Program as an important element of combining both remote and in-situ measurements for a much better understanding of the coupling between the atmosphere and the ocean.

In regards to our ocean program, one essential element is collaboration. I do not think we have a single program, within the total program, that we do not collaborate either with other domestic Federal agencies, or with the international community.

As many of you know, the interagency Committee on Earth Science has established a U.S. Global Change Research Program specifically designed to improve the scientific basis for policy-making related to global change issues.

An outline of this program was submitted with the fiscal year 1988 President's Budget. One of the principal program objectives is to establish an integrated and comprehensive monitoring program for Earth system measurements on a global scale. Clearly, satellite observations are an important element to this objective and we hope NASA will continue to be an important contributor to this research effort.

With regard to the third element, the SSMI, right now, in addition to those sensors that Mr. Pyke discussed, flying on the current DMSP, are providing significant information, as did Seasat and Nimbus-7.

In addition, the U.S. Navy's geodetic satellite, Geosat, has an altimeter which is making significant contributions.

As Mr. Pyke noted, the near-real-time synthetic aperture radar observations of sea ice will be received at Alaska's SAR facility. This will be operated at the University of Alaska, and data will be made available to NOAA's NMC for forecast impact investigations.

Currently, we are trying to buy an advanced scatterometer which we call NASA Scatterometer, NSCAT, on a Japanese ADEOS platform. That instrument has been tentatively selected for flight on ADEOS and will be launched in early 1995. We think it will make an important contribution not only to better understanding the ocean, but also, the coupling of the ocean with the atmosphere.

We are developing an altimetry mission which we call TOPEX/POSEIDON, that measures the surface topography. This instrument is a follow-on to the capabilities we developed on Seasat. In a single pass, we believe we can measure the surface of the ocean to about 14 centimeters on an absolute scale, and, after several passes, we hope to reduce that to about 2 centimeters.

TOPEX/POSEIDON, coupled with the scatterometer, are an integral component of the world ocean climate experiment, as well as a significant contribution to the TOGA experiment. TOPEX/POSEIDON, because of its specific orbit, will also enable precise determination of oceanic tides. This will contribute, in addition, to other ocean circulation aspects, and understanding of oceanic heat transport.

TOPEX/POSEIDON is a joint effort between NASA and the French space agency, CNES. NASA will provide an advanced instrument. CNES will provide, in addition to the launch, a somewhat dual solid-state capability in terms of an altimeter, and they are also providing a radiometric Doppler tracking system which they call DORIS.

A team of scientists have been investigated. They are now working on the program. We hope to launch that around June 1992. The NASA scatterometer is based upon our initial results with Seasat, and it has been designed to observe the surface roughness of the global ocean from which surface wind velocity fields can be obtained. We are negotiating to make sure that this data is available to current operational models.

We have had under discussion, at length, a follow-on to the coastal zone color scanner which flew on Nimbus-7, which quit working last year after about 10 years of data.

We thought we had worked out an agreement with the Eosat Corporation to fly what we call SeaWiFS, a compact wide field sensor, on Landsat-6. Unfortunately, the negotiations were terminated last week by Eosat and we are now looking at other opportunities to fly such an ocean color sensor.

At the present time, half of the 8-year data set we got from the CZCS on Nimbus-7 have been processed and archived, and are being put on optical disk to make available to the entire oceanic science community.

We are beginning to use, extensively, the special sensor microwave imager which will be discussed in a few minutes. This has a capability of providing daily products, and we are reducing those to make them available for the scientific community.

Alaska's SAR facility is a facility that I mentioned earlier, that not only do we hope to receive the European space agency's synthetic aperture radar data, but we also have a MOU with Japan to receive their synthetic aperture radar data from the JERS-1, and subsequently, we hope, in a joint effort with Canada—as Mr. Pyke mentioned—we have signed a letter of intent in which Canada would develop the synthetic aperture radar, NASA will provide launch capabilities, and we will share the data between the two countries.

Along that same line, we are also developing the shuttle imaging radar-C, which is a multi-wavelength, multi-polarization synthetic aperture radar. We call it SIR-C-XR. The X band is being provided by West Germany and the Italians.

All of these data will make significant contributions to our understanding of global oceans and ice fields.

In the future, we see the Earth observing system, EOS, as a high-priority candidate new start within the Office of Space Science for 1991. There are a number of facility class instruments and a number of principal investigator instruments which have been selected for those missions. The first mission we hope—is being planned for launch in late 1996. It will carry a TOPEX-POSEIDON-class altimeter and tracking system, an NSCAT-class, or better, scatterometer, a moderate resolution imaging spectrometer to provide a much improved data set that the AVHRR and the former CZCS provided.

With this sensor, it will give us the capability not only of looking at the coastal oceans, but we can do studies in places like the Great Lakes extremely well, and we are also looking to a significant improvement over the current SSMI.

A second EOS platform, to be launched later, essentially in 1998, will carry an advanced synthetic aperture radar. The international efforts being stimulated by EOS, and the complementary Japanese and European space agency platform, will provide, along with companion meteorological satellites, I think a great capability to look at and understand the coupling of the ocean, the atmosphere, the transport of ocean currents, and serve many operational purposes.

Thank you very much, and I will try to answer any questions you might have.

[The statement of Dr. Tilford can be found at the end of the hearing.]

Mr. **Hertel.** Thank you very much, Doctor. Next, we have Admiral Pittenger.

STATEMENT OF ADMIRAL PITTENGER

Admiral **Pittenger.** Good afternoon, Mr. Chairman, and committee members. I am Rear Admiral Dick Pittenger, Oceanographer of the Navy. I am pleased to be here today to discuss satellite oceanography. I have with me Mr. Robert Winokur, my technical director. In the interest of time, and with your permission, Mr. Chairman, I will summarize my remarks, and request that my written statement be submitted in its entirety into the record.

Mr. **Hertel**. Thank you.

Admiral **Pittenger**. As the oceanographer of the Navy, one of my responsibilities is to validate requirements for oceanography, including space. I also advise the Chief of Naval Operations and the Secretary of the Navy on oceanographic policy.

And I sponsor the use of the data derived from sensors, such as space sensors, to support operating forces. The need for these data, and those products is driven by the fact that our weapons systems and operating environments are becoming increasingly complex and sophisticated.

And as I mentioned this morning, Mr. Chairman, the increasing difficulty of tracking targets, particularly Stealth aircraft and quiet submarines, mandates that we understand the environment better. The ocean environment in which the Navy must operate is harsh, and it is unforgiving.

In the field of Anti-Submarine Warfare (ASW) which, as you know, is the Navy's number one war-fighting priority, success or failure depends on how well we understand and can exploit the ocean environment.

And in ASW—I have 31 years of experience in ASW—the first law of ASW is that the oceans are unfair, and we clearly have to be able to understand that environment better.

And one of the best places to view the ocean environment—as other panelists have already discussed—is from space. Indeed, the space age fostered a revolution in oceanography. The early NOAA and NASA satellites completely changed our view of what the oceans look like. Seasat, despite its short life, less than 3 months, was a huge success. It was really the precursor of the program that the Navy followed up with, the N-ROSS program, and as I am sure you all know, the N-ROSS program was cancelled by the Navy last year because it grew in cost faster than we could accommodate, in the face of other budget pressures.

The requirement for an all-weather ocean-sensing system is still valid, however, but unfulfilled. In the wake of the cancellation of N-ROSS, the Navy is now studying alternatives, and in the near term, working with NASA and with Defense Advanced Research Projects Agency (DARPA), we are seeking rights for the N-ROSS sensors. The Special Sensor Microwave Imager (SSM/I), as has been mentioned, which was scheduled to go up in N-ROSS, has been transferred to the Air Force, and it will go up in one of the Defense Meteorological Satellite Program (DMSP) Block-5 satellites, near term. The altimeter scheduled to go up in N-ROSS will go up in an Office of Naval Research DARPA-sponsored (Special Purpose Inexpensive Satellite (SPINSAT) program launched into space on a Scout rocket. That will probably happen next year.

And has been mentioned by Dr. Tilford, the NSCAT, the scatterometer—we looked for an opportunity for a U.S. satellite system to carry that very powerful sensor aloft, and failing to find the funding to do that, it is now going to Japan, in the Advanced Earth Observation Satellite (ADEOS) satellite.

We also have the Navy Geosat program which has been mentioned, and that satellite has been a very successful program. Having fulfilled its original mission for the Navy, its orbit was changed and the data is now being provided to the entire oceanographic community, and is providing very, very useful information.

We are taking this pause in the availability of satellite information to examine better use of existing data from DMSP, NOAA, and other sources of information. We are beefing up our modeling in an attempt to compensate for the lack of large quantities of good sensor data by better models. That can only go so far.

In the long term, the Navy has spent $1.6 million that was left over from the N-ROSS program, with the Air Force, to study oceanographic sensing in the DSMP Block-6 alternatives program, which is currently underway.

We are preparing a plan that may include the development of cheaper sensors, since the cost of putting a dedicated Navy oceanographic sensor system into space has really been our problem to date.

Every way we look at it, the soonest that we see a Navy system is the turn of the century.

To conclude, the data from earlier space sensors have opened a whole new awareness of the world's oceans, but we have not been able to follow through with the dedicated satellites for continuous all-weather long-term observations. We are still studying ways to achieve that goal.

Thank you very much, Mr. Chairman.

[The statement of Admiral Pittenger can be found at the end of the hearing.]

Mr. **HERTEL**. Thank you, Admiral. Next, we have Mr. Robert Corell.

STATEMENT OF DR. CORELL

Dr. **CORELL**. Mr. Chairman, members, it is a pleasure to be with you and to testify on this subject of satellite oceanography. I join you from the perspective of the science community as represented by NSF and other science agencies, to focus on ocean sciences and our sister sciences of the atmosphere, of the solid Earth, and some of the regionally significant areas, such as polar regions of the world. I would like to talk with you from a science perspective on the importance of satellite oceanography for the evolving global, environmental, and scientific interests in this Nation, and abroad.

The Earth's environment does change dynamically on all time scales and space scales, and history has demonstrated that although there is much uncertainty about the relative changes and contributions made by natural phenomena and human activities. We are beginning to gain a significant understanding of the Earth's system and how it functions.

While the focus of the U.S. global change effort and its progenitors such as the International Geosphere Biosphere Program—that global focus has significant impact on regional areas such as the Great Lakes region, the heartland of the U.S.—for these oceanic processes of which we speak much today, while global in character, significantly influence processes on the land masses throughout the world.

As Dr. Tilford indicated, an interagency effort under the FCCSET machinery of the OSTP established a committee called the Committee on Earth Sciences, specifically to coordinate and bring together a national effort that links the agencies of the U.S. Government with the scientific community (both directly through the National Academy of Sciences, and through other elements of planning within the scientific community). It is designed as a national effort that provides coherence with our international partners, both other agencies of Government, and ICSU (the International Academy of Sciences), the IGBP, and WCRP.

It is from this perspective that I will use an example to outline the importance of satellite systems to oceanography and to the whole U.S. Global Change Research Program.

The U.S. Global Change Research Program is designed with a simple premise. It is established to provide a scientific understanding, a scientific basis for both national and international policymaking, that relates to both natural and human-induced changes in the global Earth.

That is a comprehensive approach to the problem. One might ask why we have confidence that we have the capacity, in the scientific community, to address this problem?

First of all, environmental sciences have matured dramatically in the last decade. It is now prudent and realistic for us to expand our understanding from regional processes to the full globe. Put simply, the sciences are mature enough, have found enough understanding to address the full range of global change research.

But that in itself would not be enough. Probably one of the most significant reasons it is possible for us to attack such a global-scale problem is that we have both research tools and methodologies that allow us to address global-scale processes. The most significant are Earth-observing satellite systems. They have allowed us, over the last decade or two, to understand large-scale phenomenon.

We have learned how to take satellite data and give it scientific importance. Supercomputers are now available to take that data and use it to study global-scale processes. We have information management systems that, over the next decade, will allow us to make that data more routinely available to the science community, and to the operational communities of our countries.

So, we have the tools to do the job, and we have the infrastructure within the United States, and evolving in the world, so that our partners in both the U.S. and abroad can responsibly integrate this program.

There are three major objectives of the program, two of which depend heavily on satellite observations. The first is that over the next decade, we propose to establish an integrated comprehensive monitoring program of Earth systems measurements on a global scale. There really is no substitute for actually observing global change.

Satellites are one of the key components of that effort. This is not to suggest that land-based programs are not of equal importance, but without the satellites to integrate the data, bringing the data sets together, global synoptic perspective would be virtually impossible.

The second focus of this program is to substantially increase our understanding of how this Earth functions—its physical, chemical, and biological processes—how they interact, one with another, that produces this unique arrangement on "Planet Earth."

Unravelling the complex problems requires satellite data, field-based data from ships, aircraft, and other platforms on the surface of the Earth. This puts us in a unique place for the first time in history. The agencies are working together, and with the scientific community—we are in a position to do the job.

We must work together. None of us can do it alone. NSF, for example, has historically had a ground-based field program supporting ships at sea, and LIDARs and other systems that allow us to see the behavior of the Earth from the platform of the Earth itself. Satellites are the other part of that, and we depend heavily on NASA, NOAA, and DOD for satellite information.

The program of Global Change Research provides the glue, some ways in which we work across agency lines. The document, which I am sure you are familiar with, on Global Change, is a product of working closely with the academic community, through the NAS. We are also working across international boundaries to bring this together because this cannot be done by the U.S. alone.

Next week a number of our partners are going to join us here, in the United States, to explore some of the international arrangements that are necessary to undertake a global program such as IGBP and the U.S. Global Change program. Satellites play a key role. I will not review my written testimony, but I want to reinforce my colleagues who have testified before me—NOAA's operational satellite program, the evolving programs in NASA, our relationship with the Navy, say, in GEOSAT, and others, are all key components of the satellite "suite" that is necessary to understand global functions.

With that, Mr. Chairman, I think I will stop. Thank you.

[The statement of Dr. Corell can be found at the end of the hearing.]

Mr. HERTEL. Thank you very much. Dr. Baker.

STATEMENT OF DR. BAKER

Dr. BAKER. Mr. Chairman, and members, thank you very much. I am James Baker, president of Joint Oceanographic Institutions, and I am sitting here in place of Professor Carl Wunsch who was the original invitee, and who has provided written testimony, and I hope that can be provided for the record. I will just give a brief summary of the issues.

I will not use any acronyms or special names here, I think you have heard many of those already, but I hope I can speak with some conviction about the importance of satellites, not only for studying the oceans, but also for looking at coastal waters in the Great Lakes where they have been very useful.

As you know, the ocean is important to us in many practical ways—fisheries, commerce, nuclear waste disposal, national defense. Oil pollution and beach waste have been much in the news. We know that oceans steer the weather and will affect how tropical cyclones operate. The El Nino, warming and cooling in the tropics, has affected fisheries and caused floods and droughts worldwide.

We know that global change from industrial gases like CO2 may already be upon us, and we also know that the ocean is the key aspect of global change as it absorbs, transports and distributes such gases around the world.

As Dr. Corell pointed out, in order to understand this system we must observe it, and once we have that understanding we can make predictions. Traditionally we use ships, moored buoys and drifting buoys to look at the ocean, but the problem with ships and buoys is that they are limited in scope, they are slow, and they are costly.

But today, thanks to NASA and the other space agencies, there is a new technology that has been demonstrated—satellite instruments—instruments that can sit well away from the Earth and give us a snapshot view of what is happening in the ocean.

And they can give us a snapshot, not just like photography, but with a much broader range of wavelengths—microwave and infrared—so we get a much different and new picture of what the ocean is doing.

This new technology that NASA has demonstrated, and that is currently carried by operational missions, of NOAA and Navy, and by technology missions of NASA, tells us about waves, about currents, temperature, the biology in the ocean, the sea ice. It also tells us how the ocean is driven by wind and by rainfall.

These new measurements are remarkable, exciting, and given us a revolutionary view. We have seen things that we did not discover by using ships. We have seen new bottom features of the ocean; we have seen new currents; we have seen new coastal features.

As a consequence of this new technology, new scientific programs have been developed aimed at understanding the Great Lakes, the coastal oceans, the global oceans, and seeing how this all fits together in climate change.

There is the Tropical Ocean Global Atmosphere program that has already given us the first step in the prediction of the El Nino. The World Ocean Circulation Experiment will tell us about ocean currents and how they distribute heat and carbon dioxide.

The Global Ocean Flux Study will tell us how biology is a part of global change, and the new Global Energy and Water cycle Experiment will explain the hydrological cycle.

All of these programs depend crucially upon satellites. The El Nino is being studied with NOAA weather satellites and with sea-level measurements from the Navy's altimeter satellite.

The World Ocean Circulation Experiment depends crucially on a NASA-French satellite to measure ocean currents. The Global Ocean Flux Study will use satellites to measure biology in the ocean, and the Global Energy and Water cycle Experiment will use satellites to measure rainfall.

Many agencies are involved, and not just the U.S.: NASA, NOAA, NSF, and the Navy, the European space agency, the Japanese space agency, and some agencies of smaller countries.

There is a bottom line. The field programs which are necessary to carry out this activity are ready to go. The satellites have been planned, approved, and scheduled. But the field studies and the satellites must go on simultaneously if we are to get data that will be useful.

If the satellites are delayed, then we not only lose our lead in technology to other nations, but most importantly, our knowledge of how to monitor and understand the coastal ocean and global ocean is greatly delayed.

One thing the committee can do is to monitor the satellite schedules and make sure that they do stay on schedule.

In the long-run, we need to have ocean measurements made operational the way weather measurements are today. To do that, NASA needs support for development of new technology, the National Science Foundation needs support for basic scientific programs; NOAA needs support for its operational satellites, and the Navy needs support for getting its operational measurements onto the Air Force satellite.

The somewhat esoteric words, DSMP Block-6, are very important to oceanography, because that is the next series of Air Force satellites that will carry operational measurements, and if there are ocean measurements aboard that next series, then we will have long-term ocean measurements—the dream that we have had a long time.

I will stop there. Thank you very much.

[The statement of Dr. Wunsch can be found at the end of the hearing.]

Mr. HERTEL. Well, we thank you and the other panelists very much. You know, you excite us about what has been done, and how much needs to be done, and how much information has been gathered but how much more could be gathered. But as you point out, not very much is going on.

And that is very sad. First, I will ask Mr. Goss if he has any questions.

Mr. GOSS. I think I am at about the same place you are, Mr. Chairman. I have seen the menu and I like it. I have heard about the benefits. I have heard about the successes. We know of the needs, and I am sort of waiting for the next chapter. And I am not quite sure who is responsible for the next chapter.

In fact I am not even sure who the author is at this point. And I have a feeling that we probably all have an interest in trying to find out who the author is, and getting the next chapter before the public. And so my questions probably go that way, both to NOAA and to NASA. To ask specifically if I may, at this time—Mr. Pyke, is there in fact a plan to get us into tomorrow on this, from NOAA's point of view, to do some of these things we know we need to do, and are there any dollars or price tags envisaged yet?

Mr. PYKE. Mr. Goss, we are planning to continue the observations that I summarized for you earlier, as I said, into the 1990's. To continue the instruments that we are now flying; to continue the spacecraft to carry those instruments now through this next decade. And we have no plans at this time to expand on our NOAA-sponsored suite of instruments, but we do have a great deal of hope, and anticipation, at the potential availability of data for NOAA and other users, relating to ocean applications, from instruments that NASA plans to fly and those instruments that the Navy might be able to fly, as well as the Air Force, and certainly to have access to the ocean-related space-acquired data from other countries.

So we are looking forward to receiving that data, which we expect to be very substantial, over the next several years.

Mr. Goss. May I ask, then—that is good, and I have taken that message. What I cannot quite get into my mind, and maybe I am being too militaristic about this—but I do not see a table of organization and equipment that seems to be set up anywhere. I just do not quite understand how this is all coming together.

It is all good, and we want it and we need it, and we hope and we think, but who is there actually there driving it down the road on a specific channel? Is it NOAA? NASA? Is it the Navy? Is it our friends elsewhere?

I mean, that is really what I am sort of grappling with.

Dr. Tilford. I believe the effort that is driving it is the scientific community. I think, without doubt, the planning that has gone into effect over the past 5 years have laid out the kind of measurements that need to be made. I think we, through technology demonstration, along with the Navy, have demonstrated some of the capabilities.

Unfortunately, Seasat only lasted 90-some days, but what we learned from Seasat was fantastic; what we learned from the coastal zone color scanner on Nimbus-7 I think—a sensor that was put up to last 1 year that lasted over eight.

We have a plan. We are building the TOPEX/POSEIDON, the advanced altimeter. We are building the scatterometer to fly on ADEOS. We had an announcement of opportunity for the Advanced Earth Observing System that was issued in January of 1988. In February of this year, we announced the selection of a large number of investigators, both for instruments and for interdisciplinary investigations.

We are in the phase B study for that program right now. It is a high-priority initiative for the Office of Space, Science and Applications in the fiscal year 1991 budget. So, we have a number of things that are ongoing. We have a few problems.

The inability to find a place to fly an advanced color instrument is quite a setback for us. We were hoping to fly that on Landsat-6 in 1991. This is one of the most important elements of the ocean productivity program, for fisheries, for a whole number of things, including ocean circulation.

And that is a significant setback. We are looking, now, for other ways to fly that in a reasonable time frame. I think we do have a plan. I hope it is on schedule. These things are not fast, however; they do take a number of years to implement.

So, I think by 1997, we will have a significant series of satellites that have been flown, and will be flown. So I think we know where we are going. Our big hurdle is to find enough resources in order to do that.

Mr. Goss. Mr. Chairman, I do not want to monopolize this, but you have given me everything but sort of the price tag, and I realize we are out into the future, and you have mentioned that it is a hurdle, we all know that, and what I am trying to do here is to elicit the priorities that you feel are doable and that we can afford, and then get behind those—I suspect is where this line of questioning is ultimately leading.

Dr. TILFORD. I do not want to say that the program is not expensive. The program that we have laid out—and I think that the scientific community has laid out—is very expensive. We are right in the process, as I said, of our preliminary studies, and as part of the fiscal year 1991 budget we are going to bring you—we hope, assuming it is approved by both OMB and the Administration—a very aggressive, expensive program.

I think, in the meantime, we have a number of things underway that are funded and that will be flown. So next year, I will come and tell you exactly what it costs, and plead for your support.

Mr. GOSS. I thank you. Let me ask one specific, just absolutely strictly parochial specific question. I have a report—and I do not know if it is accurate or not—that talks about the Geostationary Environmental Satellite program, and it talks about one sort of fading out, and another I guess has faded out now, and we are going to lose the next one, and that translates, to me, into trouble on another subject we were talking about this morning which is a relatively accurate bad weather forecaster of hurricanes. Particularly it is of great interest in the coastal areas.

Can you give me any confidence or any good news on the subject of that capability, and that specific system? Whoever is best qualified.

Dr. TILFORD. I will defer to Mr. Pyke.

Mr. GOSS. Thank you, sir.

Mr. PYKE. Mr. Goss, we are in a "one GOES" situation, as I am sure you know at the present time, and although a lot of effort has been expended toward the GOES program over the years, there has been some unfortunate luck including a launch failure a few years back. Yet despite the fact that the last GOES lasted longer than the 5-year nominal lifetime, it recently bit the dust, and the one GOES that we have is in excellent shape, and we are nursing it along very, very carefully.

We are moving it from season to season. We will be moving it to the east in order to be able to provide good coverage of the hurricane season coming up this next year, and then back to a slightly more westerly location in order to provide the best coverage for the winter storm season.

With one GOES, although it is healthy, we are left with a situation where we do not have good observations out into the Atlantic. We cannot see hurricanes as they are spawned. We do not have adequate coverage in Alaska nor do we have adequate coverage in the area of Hawaii, and looking at storms that come in over the Pacific.

During this period of time, with one GOES coverage, we augment our data for our weather forecasters with data from our polar-orbiting satellites, and we also make use of data from the European EDIOSAT [phonetic] and from the Japanese GMS, both of the geostationary satellites that look at other parts of the world, that begin to encroach on the areas we normally cover. We are doing everything we can to move ahead and have a new GOES—which is currently called GOES-I—available for launch—we currently expect in 1990, and we are preparing to bring that new GOES, with its enhanced capability on line, and available for use by forecasters just as soon as possible.

Mr. Goss. Thank you very much. Thank you, Mr. Chairman.

Mr. HERTEL. Of all the things that you have talked about gentlemen, that would be good to do for the future, there is not a technology problem with any of them, right? Doctor, we have the technology for all the things that you are fighting for, or requesting?

Dr. TILFORD. I think we are very comfortable in saying that we are at a level where we can utilize the current state-of-the-art technology to provide most of the measurements that the scientific community requires.

Mr. HERTEL. And as far as having enough coverage, Mr. Pyke, of those different areas you just mentioned earlier, that is only a problem of cost. We have the technology, obviously, to do all those things.

Mr. PYKE. Yes. We have the technology. I should say with regard to the GOES satellite, the new GOES satellites, that we are pushing the capabilities of the available technology in developing instruments that will provide us a significant improvement over our current capabilities.

Mr. HERTEL. What concerns do you have that it is going to harm our research by relying so much on foreign satellite technology in support of ocean science?

Dr. TILFORD. I think there are a number of concerns, always, when you are negotiating with the international community in order to have full access to data for operational purposes. Now, from the research point of view, I think things are going reasonably well, and we can get most of the data that we require, I believe in a retrospective approach, for R&D purposes.

There are certain areas—and perhaps Rear Admiral Pittenger could touch on those more—but in terms of getting real-time data from all the existing satellites that are going to be flying in the next decade, we do anticipate some difficulties. We are trying to work through those on a case by case basis, but unlike the situation where the U.S. furnishes most of the data from the polar-orbiting METSATS (meteorological satellites) and the geostationary satellites to the World Meteorological Organization. We have not yet established the same kind of capability in the oceanographic community.

Mr. HERTEL. Admiral, you mentioned at the end of your testimony a program that would not be able to go forward till the turn of the century. Which program was that?

Admiral PITTENGER. The program that we are looking at to satisfy the Navy's requirements is the DMSP Block-6, and the schedule for that looks like about 2102.

Dr. TILFORD. 2012?

Admiral PITTENGER. Or 2002. I am not that pessimistic.

Dr. TILFORD. Well, you are further out than we are.

Mr. HERTEL. It might take that long.

Admiral PITTENGER. We are deeply involved in long-range planning.

[Laughter.]

Admiral PITTENGER. It's 2002. And that is based primarily on the good news that the DMSP Block-5 satellites are having longer life than was previously anticipated. If I could comment on the issue of the international programs that the—there is no question, in my mind, that the programs that were described here today will be useful to the Navy in terms of understanding the oceans better, and those data will be used by the Navy as they are made available.

The real issue with the use of these data from international programs is a matter of timeliness. The Navy's interested in nowcast and, basically, what happens when the data comes to you time late is that you get hindcast, and that is not very useful to the operating forces. In both the East and the West, in the European and ERS consortium, and with Japan, there are political problems with us, with the military getting direct access to those commercial satellite data. And that is exactly why the Department of Defense feels that it needs a dedicated program, so that it can access those data directly.

Mr. HERTEL. Yes, but at the same time, they are talking about the turn of the century for that one. They have reduced the money, you said, for the N-ROSS?

Admiral PITTENGER. The N-ROSS program was cancelled.

Mr. HERTEL. Cancelled.

Admiral PITTENGER. Finally cancelled last May, 1988.

Mr. HERTEL. But isn't there still a need for that information?

Admiral PITTENGER. Yes, sir. There is still an operational requirement, and as I tried to say in my testimony, our plan is to seek ways of satisfying that requirement by other means. Actually, the N-ROSS program was going to be a gap-filler to DMSP Block-6 in any case.

It was going to fill between now and whenever DMSP Block-6 becomes operational, which, at the time, was, really, just the end of the 1990's. Now it has slipped a couple of years.

Mr. HERTEL. But what other means could we have to meet those requirements?

Admiral PITTENGER. Well, what we are doing is using better the information that is out there. We flat do not satisfy all the Navy's requirements. We do not have an all-weather capability, although we use NOAA satellite information for sea-surface temperature, for example. Their sea-surface temperature sensor does not see through clouds. So, in the northern latitudes which in some times of the year are covered 85 percent with clouds, we are not able to get the data that are needed by our ASW forces.

Mr. HERTEL. I do not understand why the Navy does not see that as an important priority. I am confused. We have to protect our ships and defend our Nation. If we do not have that information, that could lead to some very dangerous situations.

Admiral PITTENGER. You are absolutely right. I mean, we do see it as important, and as I say, we left the requirement on the books, and we are in the process of doing work around at this point.

Mr. HERTEL. What is the problem with our allies, our friends, not giving us full information for our military when our military is defending them? What is the problem there, with the Japanese, and any others?

Dr. TILFORD. Well, let's take the case with the Japanese, especially. There have been certain working relationships between the U.S. and the Japanese, and there are certain implications with the Japanese government and the Japanese public, that even though we do have certain treaty relationships, that the kind of information that the civil Japanese community might provide to the DOD would make it extremely difficult to sell those programs in Japan. That is putting it—a fair assessment.

Mr. **HERTEL**. Politically?

Dr. **TILFORD**. It is a political problem, yes.

Admiral **PITTENGER**. They do not provide that data to their own military, sir.

Mr. **HERTEL**. Admiral, I do have to ask. I mean, the Navy receives the largest percentage of our defense funding, and they have worked to get all the ships up. I do not understand, again, why they do not want to have all the information they need to protect those ships, just from a military standpoint, aside from the scientific. I do not understand that.

Dr. **TILFORD**. If I could answer. I think the Oceanographer of the Navy has been very, very supportive——

Mr. **HERTEL**. I do, too.

Dr. **TILFORD** [continuing]. Of the satellite programs.

Admiral **PITTENGER**. Well, thank you for your defense.

Mr. **HERTEL**. What reasons do they give, I guess, so I can ask them, to follow up? They have got to say something when they——

Admiral **PITTENGER**. Without getting classified, let me just say that in the past—now let me just talk about ASW. The fact is that we have handled this problem without this kind of data. What we are looking toward is the future submarine threat, when the targets get so quiet that we have lost the larger signal to noise ratios that we enjoyed previously, and when we do that, we really have to be able to exploit the environment to its fullest. And so I am saying that as the targets get quieter, we have to have this capability.

We are, you know, looking at work-arounds. As I said, the—and I did not mention the Geosat. We are using that data to good advantage, to come up with global circulation, particularly large oceanographic features such as the Gulf Stream, and we are about to launch a second altimeter which will continue our ability to use that.

And we took, as I mentioned, the microwave imager, the SSM/I, which was scheduled to go up in N-ROSS, and have delivered that to the Air Force, and that will give us surface winds, which is a very important element, let's us do global weather, and the weather drives our circulation models.

Mr. **HERTEL**. Thank you, Admiral. Dr. Baker, did you want to comment further on the previous question?

Dr. **BAKER**. Yes. I just had a brief comment. I would like to say, I believe the Navy—although they did have a false start with N-ROSS—has really done a marvelous job in putting up what they call Geosat—which is a satellite that measures the shape of the ocean, and now they are planning to put up a second such satellite which I think will give us a comprehensive new view of ocean eddies, for example.

And it is true, what Dr. Tilford talks about—if the research programs and the research technology that are in place stay on schedule and continue to operate, we will have a very strong research program. But we do have a problem. The problem is that we do not have a national commitment, or a national organization for operational ocean measurements, and the two agencies that are involved there are NOAA and the Navy.

And we need, I think, congressional help to urge these agencies—for example in the case of NOAA it is a question of getting the funding to actually have a robust operational system.

Right now, we barely have an operational meteorological system in place. We have lost one geostationary satellite. We do not know where the funding is going to come from in the long-run. A serious issue, even for the weather measurements. And we do not have in place an operational ocean measurement capability from satellites, which should also be part of the civil, NOAA activity.

Now, as far as the Navy is concerned, where you need ocean measurements is on the Defense Meteorological Satellite program. That program needs to have some ocean instruments. The place that it can be affected is in the planning for the satellites that will up at the end of the century, as Admiral Pittenger mentioned. That is the next series, or Block 6. But the planning is being done now. The decisions will be made in the next couple of years about what instruments will be put on.

If the decision is made to have no ocean instruments, we will not have operational ocean measurements. So we have a near-term problem for a long-term issue, and that is making decisions about operational ocean measurements.

Mr. **Hertel**. Well, let me reemphasize at this point Dr. Corell's conclusion at the end of his written statement about the fact that we are losing time and not moving ahead, and let me quote from Mr. Wunsch's statement that you submitted, Dr. Baker, in a few spots.

He says, "Who is responsible for assuring that the U.S. will properly observe the global ocean from space and from within over the long-term? It appears that no one is. Many outsiders think that NOAA plays this role. It does not."

And then at the end of his submitted statement, he says, "The current global change interest is of course highly welcome in general terms. But climate and global change are long-term problems that history suggests will wax and wane in public and congressional attention. To really answer the questions which press on us will require many years and decades of hard, often unglamorous work, directed at unravelling many complex and subtle scientific and technical issues. There is a grave danger that the urgency and attention being lavished on these problems will lead to inappropriate reorganizations, program plans, and hardware ill-suited to the long term."

I think that by the jurisdiction of our subcommittee, those are the things we have to look at. We commend you for what you are doing, and we commend you and thank you for the information you have brought us here today, and we are happy to hear about the plans that are moving ahead.

But it is clear that the deficiencies are very great, and it is clear that the responsibilities are ill-defined as far as the overall direction that we need, and I think that that is something that the subcommittee, by necessity, must look into further.

So we thank you very much for your time today, and we will be in touch with you. We have many more written questions for you to answer at your leisure, but we appreciate all of your help today. Thank you.

[Whereupon, at 3:10 p.m., the subcommittee was adjourned, subject to the call of the Chair.]

[The following was submitted for the record.]

RESPONSES TO QUESTIONS SUBMITTED BY HON. DENNIS M. HERTEL, CHAIRMAN, SUBCOMMITTEE ON OCEANOGRAPHY AND THE GREAT LAKES, TO REAR ADMIRAL RICHARD F. PITTENGER, OCEANOGRAPHER OF THE NAVY

OPERATIONAL OCEANOGRAPHIC REQUIREMENTS

Question. Does the Navy have operational oceanographic requirements that are not being met?

Answer. A number of operational oceanographic requirements have yet to be satisfied. Global ocean measurements under all-weather conditions remain a major challenge. Persistent cloud conditions in regions of high operational interest prevent frequent measurement of important ocean parameters such as sea surface temperature and wind speed and direction. Frequent high resolution observations over broad areas of Arctic sea ice are also limited by cloud cover, a problem that can be overcome through the use of synthetic aperture radar. Accurate determination of the three-dimensional ocean thermal structure through a combination of space-based in-situ measurements remains a requirements of high priority.

OCEANOGRAPHIC REQUIREMENTS IMPROVED WITH SATELLITES

Question. What operational oceanographic requirements could be improved with satellites?

Answer. Satellites provide the capability to frequently measure ocean parameters on a global basis. This frequent coverage of the global ocean permits the measurement of the variability in ocean features and the initialization of models used to predict future ocean conditions. Satellite platforms permit the co-location of sensors which allows the simultaneous measurement of multiple global ocean parameters and measurement consistency not otherwise obtainable. This grouping of measurements simplifies the ground processing methods and systems. In addition, satellite systems permit ocean measurements in frontier regions and areas of denied access.

SATELLITE TECHNOLOGIES

Question. The testimony you provided on April 27 dealt with existing satellite technologies. Where are the perceived breakthrough technologies and are we adequately funding the technology base for those basic requirements?

Answer. Several new technologies, if exploited, can contribute to a space-based, all-weather ocean measurement capability to support Navy operations. Advanced passive microwave radiometers, innovative antenna configurations, and data processing methods offer the potential for fine-scale sea surface temperature measurements. Laser-based LIDAR systems show promise in terms of subsurface measurements, while an ocean color measurement capability can enhance the LIDAR effectiveness as well as provide unique measurements for fronts, eddies, and marine-life elements important to acoustic system performance. Synthetic aperture radar measurements from space have been adequately demonstrated. Exploiting this measurement capability, in both sea ice and open ocean areas, requires new understanding of processes and new interpretive skills. Current budget constraints preclude investments in these emerging technologies sufficient to bring them to operational maturity during the next decade. Significant increases in funding for investments in sensor engineering and algorithm development are required to accelerate the transition of these technologies to operational use.

INNOVATIVE LESS-COSTLY SENSORS FOR SPACE OCEANOGRAPHY

Question. With the demise of the N-ROSS program, are there other more innovative, less costly sensors for space oceanography?

Answer. Affordable space sensors are one element in achieving a cost-effective operational capability in satellite oceanography. Present space-based ocean sensor technology developed to support science investigations is often too costly to inherit for operational missions. Investments are needed in the development of multi-purpose sensors incorporating innovative antenna, circuitry, and structure technologies in order to reduce the cost of future operational ocean sensors. Cost efficiencies may also be realized through a selective relaxation in sensor measurement accuracy, while realizing an overall improvement in operational utility through the use of improved model physics and data assimilation methods. In addition to innovative sensor designs, low-cost launch capabilities coupled with modest, flight-proven satellite platforms are needed to realize an overall space oceanography capability that is affordable to the Navy.

PLAN OF FUNDING PROFILE, OCEANOGRAPHIC SENSING

Question. If we asked you for a detailed plan with a funding profile for near real time, oceanographic satellite sensing, could you provide it to us?

Answer. Considerable planning has been undertaken, both during the evaluation of N-ROSS, and subsequent to its cancellation, regarding the development and operational utilization of satellite oceanography in the Navy mission. Plans exist for the operational exploitation of present and future approved satellites to the year 2000. Additional planning is underway which reflects a Navy participation in the Block 6 version of the Defense Meteorological Satellite Program (DMSP) as a means of achieving an operational satellite oceanography capability in the years 2002 and beyond. Drawing upon these planning activities, a detailed plan including funding requirements could be provided.

COORDINATION OF THE OCEAN SATELLITE POLICY

Question. What federal agency is responsible for the coordination of U.S. ocean satellite policy? What are the objectives of this policy? Is there a plan or strategy for gaining access to the needed technology:

Answer. At present there is no federal agency providing for the coordination of U.S. ocean satellite policy. Navy policy in terms of space-based ocean measurements is formulated from operational fleet requirements. There is considerable coordination of satellite initiatives and programs on an informal basis between NASA, NOAA, and Navy which aids in shaping cooperative efforts in satellite oceanography. Interagency working groups and committees have provided the medium for this coordination, and have often yielded strategies in support of both research and application programs. Many of the technologies needed to implement an operational oceanographic satellite capability in support of Navy requirements are available now. Applying these technologies in an affordable fashion remains a challenge which is being given emphasis in Navy research and development budgets beginning in fiscal year 1990.

POLICIES REGARDING DISTRIBUTION OF SATELLITE DATA

Question. What are the current policies regarding the distribution of satellite data among agencies and within the academic community and private sector? Do these policies foster maximum access to important oceanographic information for each of these user groups?

Answer. The policies affecting the distribution of the retrospective satellite data to users are established by NOAA and administered by NOAA's National Oceanographic Data Center and Satellite Data Services Division. Space-based oceanographic data in these NOAA archives are available equally to government, academic, and private sector users on a fee basis. To augment these current distribution capabilities an Interagency Working Group on Data Management for Global Change is formatting a computer-based network to permit broad national access to major archives of environmental data, including satellite-derived oceanographic data, for use by all users involved in research and applications projects. This national network will be available in the 1995 time period to greatly enhance the access and distribution of data. The distribution of near real-time satellite-derived oceanographic data at present is generally limited to data exchange between NOAA, Navy, and the USAF to support operational analysis and forecasts.

DEFINING THE BATTLEFIELD FOR NAVAL COMBAT

Question. As Oceanographer of the Navy, you are charged with defining the battlefield for naval combat, both on the surface. Looking toward the 21st century, could you describe for the subcommittee what technologies and capabilities we need to aggressively pursue?

Answer. To define the Naval battlefield with sufficient spatial and temporal resolution to support 21st century warfare will require hybrid systems which combine remotely sensed environmental information fed to weapon systems that are also capable of sensing their local operating environment in real time. This powerful combination of capabilities will create smart weapons that can react to environmental conditions and use them to their advantage. Additionally, in order to combat the perceived future threat, Navy weapon system developers must take a revolutionary approach to weapon system design. Examples in ASW are active, low frequency systems or sensors which work in the very low or ultra low frequency regimes. Support to these systems requires significant investment in environmental remote sensing techniques, both space and earth based. Also required are large investments in data assimilation and fusion techniques, coupled to sophisticated numerical models, to make the information usable and not overload the operator. This means more emphasis in innovative computer techniques with improved displays and artificial intelligence functions.

OCEANOGRAPHIC DATA FROM FOREIGN SOURCES

Question. Has the Navy experienced any difficulty in getting oceanographic data from foreign sources? If so, from whom and what was the reason for the difficulty?

Answer. The Navy has experienced little difficulty in getting oceanographic data from foreign sources, particularly since bilateral agreements with foreign countries are effective and comprehensive. One exception is the refusal by Japan to deliver meteorological satellite data to military users due to restriction on release set forth in the Japanese Constitution. Problems in obtaining meteorological satellite data from India are expected to be resolved in a joint USN-NASA initiative to set up communications facilities within the country to obtain satellite data from the India receiver site and relay it to US customers.

TESTIMONY
OF
THOMAS N. PYKE, JR.
ASSISTANT ADMINISTRATOR FOR SATELLITE
AND INFORMATION SERVICES
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

BEFORE THE

SUBCOMMITTEE ON OCEANOGRAPHY AND THE GREAT LAKES
COMMITTEE ON MERCHANT MARINE AND FISHERIES

U.S. HOUSE OF REPRESENTATIVES

APRIL 27, 1989

Mr. Chairman and Members of the Subcommittee:

Thank you for inviting me to discuss the role of NOAA's environmental satellites in oceanography. In my testimony, I will review primarily the history and current status of oceanographic missions carried out by our operational remote sensing spacecraft.

Today, remote sensing of the ocean utilizing weather satellites is useful to the fishing, maritime shipping, and the offshore energy industries, as well as for global environmental research and defense. However, the reason for attempting oceanography from space in the first place was to improve weather forecasts.

Origins of satellite oceanography

Today's computer-generated weather forecasts rely on numerical model descriptions of the atmosphere. In the decades preceding operational satellites, the patriarchs of weather forecasting pointed out that air-sea interaction models were essential input to good numerical weather predictions. The array of conventional ship and buoy observations was and still is inadequate for depicting the thermal properties of the Earth's vast ocean surface. The obvious strength of NOAA weather satellites is that they yield environmental observations over enormous areas where no ground-based observers exist.

In the late 1960s, thoughts in weather forecasting circles turned to satellites as potential sea surface temperature observers. Polar-orbiting satellites were perfectly situated for these observations in that they provided global coverage of the oceans. Research scientists speculated that satellites "may prove almost as useful as ships" for providing the broad-scale sea surface data needed for environmental predictions.

At the same time, other scientists pointed out that the utility of satellite-based sea surface temperature maps would extend to the maritime industry, particularly to fishing. However, when researchers were looking at the first crude sea surface temperature analyses based on data from the NASA Nimbus II spacecraft in 1966, the captain of a tuna boat or oil tanker would have dismissed remote-sensing satellites as research toys.

Satellite sea surface temperature products

Operational remote sensing of the sea has come a long way since the 1960s. NOAA began producing weekly ocean thermal analyses in 1973 based on data from ships and our NOAA-2 polar-orbiting satellite. The spacecraft carried an infrared radiometer -- an instrument which sensed infrared, or thermal energy emitted from the surface and the atmosphere. This was a meteorological instrument, but since one of its viewing channels offered a view of the Earth and sea surface that was relatively unattenuated by the atmosphere, we used it to derive sea surface temperatures. The sea surface temperature charts that were produced were distributed to NOAA's National Weather Service (NWS) for use in adjusting their weather predictions.

In the private sector, the uses of satellite-derived sea surface temperature maps began to unfold in the mid-1970s. In 1975, a fleet of eleven Exxon tankers was used to prove the benefit of satellite-based current analyses for navigation. Five of the ships received satellite-derived maps of the Gulf Stream and were told to use them for routing from the Gulf of Mexico to the Northeast. The other six did not receive them and navigated by customary means. The savings were significant: Exxon estimated that 31,500 barrels of fuel oil per year could be saved by its fleet of fifteen tankers using satellite data to find the stream northbound and avoid it southbound. The maritime shipping industry now makes extensive use of satellite-based sea surface analyses worldwide.

Satellite success stories from the fishing industry are many. Entire fleets now rely on satellite-derived ocean thermal boundary charts, radioed from the NWS or private consultants, to save fuel and increase catches by identifying the most likely areas of high fish concentration. Satellite-derived sea ice charts, used primarily by the Navy, are also being used by fishermen in Arctic regions.

NOAA satellite oceanography comes of age

The 1978 launch of the improved "third-generation" polar-orbiting environmental satellite known as TIROS-N was a milestone for satellite oceanography. Its new sensor, the Advanced Very High Resolution Radiometer (AVHRR), meant new accuracies for space-based operational sea surface thermal analyses. The AVHRR resolution was finer, about 1 kilometer, and the sensor was less noisy than that of its predecessors. Spectral response and calibration were better, allowing us to better account for atmospheric effects on sea surface temperatures. Computer power had increased substantially, too, allowing us to produce regional maps two to three times weekly at a resolution of 14 kilometers. Global distribution of sea surface temperature maps burgeoned as a greater variety of users, commercial and government, operational and research, began receiving them on a subscription basis.

In 1981, further improvements to our oceanographic products suite were brought about by the launch of the NOAA-7 satellite, a new version of the TIROS-N spacecraft with a 5-channel AVHRR. Our scientists developed a new multichannel sea surface temperature scheme using this advanced instrument with overall accuracies routinely within 0.7 degrees Celsius.

Satellite oceanography has become vital to the study of climate change. Sea surface temperature measurements and studies of oceanic circulation require the global coverage provided by satellites. The 1982-83 El Nino event, for instance, was sensed by the NOAA AVHRR and seen in the sea surface temperatures. This information is invaluable for determining future El Nino events by tracking the extent of sea surface warming across the tropical Pacific.

NOAA's NWS oceanographers at Washington, Miami and San Francisco use NOAA satellite image data to show the boundaries of ocean currents, as well as to delineate small-scale thermal fronts such as those generated by wind-induced coastal upwelling. Mapping other small-scale features has proven valuable to a variety of researchers and real-time decision makers.

NOAA CoastWatch

The NOAA CoastWatch program of monitoring the environmental quality of the Southeast coast grew out of efforts to identify the transport of the unprecedented North Carolina red tide of 1987-88, which ravaged the State's shellfish and tourism industries. NOAA satellites could not see the red tide directly, but did identify the filament of unusually warm water which broke away from the Gulf Stream and transported the devasting red tide algae bloom onto the coast.

NOAA has been producing near-real time products from its environmental satellites and forecast models for use by NOAA

National Marine Fisheries Service oceanographers who continue to monitor the Southeast Coast for red tide and other environmental phenomena. High-resolution satellite-derived sea surface temperature images are now distributed to scientists who can provide alerts of any future occurrence to State and Federal response agencies. We expect this CoastWatch program to continue into the 1990s and to expand to include other coastal areas.

Sea ice monitoring

Another application of the AVHRR instrument has been for global ice mapping. Scientists have been using satellite visible and infrared image data to map polar ice concentrations since the 1960's, and operationally since 1976 when the NOAA-Navy Joint Ice Center was formed. Ice maps and ice forecasts are issued by the Center two-to-three times weekly for defense and maritime industry requirements.

Ice often poses a safety and economic threat to the shipping industry on the Great Lakes. Here NOAA satellites, including the Geostationary Operational Environmental Satellites (GOES), have been used to map the winter season ice advance and retreat. The first locus of Great Lakes ice mapping was in the NWS Forecast Office in Ann Arbor, Michigan. In the early 1980s, responsibility shifted to our Joint Ice Center. Nearly 90 percent of the data for these ice analyses is obtained by NOAA's polar-orbiting satellites.

Other applications

Aside from the enormous successes of NOAA's radiometric thermal analyses from space, several other marine environmental phenomena have been studied from our satellites. Analyses of sedimentation of river deltas, estuaries, and bays, and pollution plume surveillance have been demonstrated with mixed success. The strength of NOAA's polar-orbiting satellite system in these cases is in its orbital cycle. The TIROS-N series spacecraft can view each spot on Earth twice daily, once in darkness and once in daylight. One weakness in this system as it is used for oceanography, is that the AVHRR instrument cannot see through clouds, which may obscure the phenomena we wish to observe. Sensor resolution and the nature of the ocean-surface phenomena being observed are also limiting factors in surveillance by the AVHRR. Oil spills, for instance, must be at least several kilometers on a side, thick enough to be differentiated from the uncoated water surface, and must be overflown at the correct angle relative to the sun to capture solar reflection of the surface sheen in order to be seen.

Future remote sensing instruments will partially overcome the cloud-cover problem. For instance, an advanced microwave sounding unit, (AMSU), slated to fly on the next generation of NOAA polar-orbiters beginning in about 1993, will allow us to better estimate sea ice edges through persistent cloud cover.

Other Satellite Sensors

Other remote sensing instruments have been flown on research spacecraft with applications for oceanography. Coincident with the advent of the TIROS-N series was the Coastal Zone Color Scanner (CZCS), on the NASA Nimbus VII satellite. Our research oceanographers completed many studies intercomparing AVHRR thermal data with ocean color variations linked to seasonal nutrient changes and algae activity.

In studies of the El Nino, CZCS data showed biological changes in areas of unusual surface warming in the equatorial Pacific coast.

Two other types of remote sensing instruments are altimeters and scatterometers. Each of these will be flown on the European Space Agency's ERS-1 satellite, to be launched in 1992. NOAA will receive sea level and sea state analyses from the altimeter data, and surface wind speed and direction analyses from the scatterometer data, for weather forecasting and global change studies.

In addition, ERS-1 will carry a synthetic aperture radar (SAR) instrument. This cloud-piercing sea surface observer will provide observations of ocean wave spectra with a resolution about 25 meters. NOAA is planning to access a limited amount of this very high density data through a readout site in Alaska. In addition, NOAA and NASA are in the process of developing a memorandum of understanding with Canada for government, and private-sector use of synthetic aperture radar data from the Canadian RADARSAT spacecraft to be flown in the mid-1990s.

As you may know, the Interagency Committee on Earth Sciences (CES) has established the U.S. Global Change Research Program, which is specifically designed to improve the scientific basis for policy making related to global change issues. This Program was outlined in the report entitled "Our Changing Planet: A U.S. Strategy for Global Change Research", which accompanied the Fiscal Year 1990 Budget. The CES will continue to ensure that a well coordinated and effective research effort is maintained. In fact, one of the principle program objectives is to establish an integrated and comprehensive monitoring program for earth system measurements on a global scale. Clearly, satellite observations are an important element in meeting that objective. NOAA will continue to be an important contributor to this program.

Summary: Satellites help put the "O" in NOAA

NOAA's satellites are among the Nation's prime tools for observing the global ocean for input to weather forecasting, global change research, and commercial maritime interests. Whether it is a yachtsman eyeing the meanderings of the Gulf Stream before a race, the captain of a fishing boat looking for nutrient-rich upwelling boundaries off California, or a research oceanographer studying the vexing thermal cycles of the equatorial Pacific, NOAA's two operational polar-orbiters command an olympian view of the globe and afford observations far in excess of random surface reports. We are proud of their track record and of their success at putting the "O" in NOAA from space.

Satellite data represent only part of the picture of NOAA's ocean observations. Satellites can measure only certain properties of the surface of the ocean. Surface and subsurface measurements are also important. Among their uses is the validation of satellite data. We must maintain an integrated mix of conventional and satellite ocean observations.

Our plans call for continued operation of the polar-orbiting satellite program through the 1990s, with launch of the first of our next generation of these spacecraft, NOAA K, in 1993. We also plan to continue our efforts to acquire and use data from sensors flown by NASA and our international partners as we move toward the next century.

Mr. Chairman, that concludes my statement. I will be happy to answer any questions that you or Members of the Subcommittee may have.

STATEMENT OF

DR. SHELBY G. TILFORD

DIRECTOR, EARTH SCIENCE AND APPLICATIONS DIVISION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

BEFORE THE

HOUSE MERCHANT MARINE AND FISHERIES

SUBCOMMITTEE ON OCEANOGRAPHY

HEARING ON SATELLITE OCEANOGRAPHY

27 APRIL 1989

Mr. Chairman and Members of the Committee: I am pleased to be here today to discuss the National Aeronautics and Space Administration's (NASA's) Oceanic Processes Program, space observations, and some of the instruments that have, or are planned to be, flown in space. I will also briefly discuss some of the international cooperative efforts in which NASA has been involved recently.

The goal of NASA's Oceanic Processes Program is to understand, and ultimately to predict, the role of the oceans in global change. The Program objectives are to: (1) develop spaceborne techniques and evaluate their utility for observing the oceans; (2) apply these techniques to advance our understanding of the oceans and their interaction within the global earth system; and (3) assist users as appropriate with the operational utilization of these techniques. Work over the past decade has primarily been focused on the first of these objectives, particularly using data from NASA's Seasat and the series of Nimbus missions, as well as the Advanced Very High Resolution Radiometer (AVHRR) on the NOAA series of operational meteorological satellites.

Based on successes with these missions, the international scientific community has responded with plans for a number of global experiments--the World Ocean Circulation Experiment (WOCE), the Tropical Ocean Global Atmosphere (TOGA) program, and the Joint Global Ocean Flux Study (JGOFS) being three notable examples--which are directed toward the second objective noted above and whose U.S. component efforts are supported by the National Science Foundation (NSF), the National Oceanic and Atmospheric Administration (NOAA), and NASA. These experiments require the broad areal coverage of surface characteristics of the oceans which can be obtained only from space, as well as complementary subsurface observations, which can be obtained only by ship and other in-situ means. Such experiments, which are conducted under the auspices of the World Climate Research Program (WCRP) and the International Geosphere Biosphere Program (IGBP), offer the potential for understanding the role of the oceans in global change.

It should be noted that a central and essential element in the conduct of oceanography is collaboration, on an interagency and/or international level. No single agency or country can afford the requisite resources to collect the spaceborne and in-situ observations necessary to observe entire ocean basins. As is noted below, there is no effort underway within NASA's Oceanic Processes Program which does not involve one or more collaborative partners.

As many of you know the interagency Committee on Earth Science (CES) has established the U. S. Global Change Research Program (USGCRP) specifically designed to improve the scientific basis for policy making related to global change issues. This Program was outlined in the report entitled "Our Changing Planet: A U. S. Strategy for Global Change Research" which accompanied the FY1990 Budget. The CES will continue to ensure that a well coordinated and effective research effort is maintained. In fact, one of the principal Program objectives is to establish an integrated and comprehensive monitoring program for Earth system measurements on a global scale. Clearly, satellite observations are an important element of this objective. NASA will continue to be an important contributor to this research effort.

With regard to the third objective, the Special Sensor Microwave Imager (SSMI) flying aboard the current Defense Meteorological Satellite Program (DMSP) missions has derived significant benefit from lessons learned from the microwave radiometer which was aboard both Seasat and Nimbus-7. Similarly, the U.S. Navy's Geodetic Satellite (Geosat), as well as its recently approved follow-on satellite, have benefited from the altimeter aboard

Seasat, as well as from the development work on the altimeter planned for the Topex/Poseidon mission. As noted below, near-real-time synthetic aperture radar (SAR) observations of sea ice to be received at the Alaska SAR Facility will be available to NOAA's National Meteorological Center (NMC) for forecast impact investigations. Studies are underway to assess the feasibility of making data from the NASA Scatterometer (NSCAT, planned for the Japanese ADEOS mission) also available to NMC.

TOPEX/POSEIDON. Based on success with the microwave altimeter which flew aboard Seasat for 90 days in 1978, the TOPEX/POSEIDON mission has been designed to observe the surface topography of the global oceans with a single-pass accuracy of approximately 14 centimeters and an ability to detect changes as small as two centimeters when in a repeating orbit. These data will enable a determination of the time-variable component of the oceanic circulation as well as the mean component at scales larger than several thousand kilometers (i.e., those scales for which the marine gravity field is well known). As such, TOPEX/POSEIDON will be an integral component of WOCE, as well as a significant TOGA experiment.

TOPEX/POSEIDON will also enable a precise determination of the oceanic tides, as well as contribute toward an enhanced understanding of oceanic heat transport when combined with the appropriate in-situ observations. Although improved knowledge of the Earth's gravity field--obtainable from a dedicated gravity mission--will enable the mean component of the oceanic circulation to be determined at scales less than several thousand kilometers, no gravity mission has yet been approved for flight.

TOPEX/POSEIDON is a joint altimetry mission involving NASA and the French Centre National d'Etudes Spatiales (CNES). NASA will provide an advanced dual-frequency altimeter, microwave radiometer, retroreflectors for ground-based laser tracking, an experimental Global Positioning System tracking receiver, and the spacecraft. In addition to the Ariane-4 launch vehicle, CNES will provide an experimental single-frequency solid-state altimeter and a radiometric Doppler tracking system called DORIS.

NASA and CNES have selected an international team of scientists comprising 38 investigations drawn from the United States, France, Japan, Australia, Great Britain, the Netherlands, the Federal Republic of Germany, Norway, and South Africa. In addition to providing guidance and advice for the mission, this team will be planning for the initial utilization of TOPEX/POSEIDON data.

Due to the cumulative cuts in NASA's proposed budget for TOPEX/POSEIDON in each of the past three years, the launch has been delayed six months to its present date of June 1992. This in turn necessitated a corresponding slip in plans for WOCE. This delayed launch date is predicated on NASA receiving the full proposed funding level for TOPEX/POSEIDON in its FY1990 budget request, as well as encountering no new unanticipated problems in the development of this mission. Further delays will likely result in penalty payments by CNES to Arianespace, as well as impede planning on the part of the international scientific community. This planning involves scheduling the large blocks of ship time required for experiments such as WOCE and TOGA. The current June 1992 launch date will permit a three-year overlap with these experiments.

NASA SCATTEROMETER (NSCAT). Based on our success with the microwave scatterometer on Seasat, NSCAT has been designed to observe the surface roughness of the global oceans, from which the surface wind velocity field can be determined. More than 90% of the global oceans can be covered every two days with a 50-km resolution.

Taken together with TOPEX/POSEIDON, it will be possible to observe the atmospheric wind forcing and ocean current response. Thus, NSCAT--like TOPEX/POSEIDON--will be a significant contributor to both WOCE and TOGA, and will provide requisite data for wind-forced ocean models, as well as surface observations for atmospheric circulation models. The NASA Ocean Data System (NODS) at the Jet Propulsion Laboratory has been established to facilitate the generation of higher-level geophysical products from satellite altimeters, scatterometers, and related sensors, as well as the archival and distribution of these products to the broad research community.

NSCAT was originally proposed to fly aboard the Navy Remote Ocean Sensing System (N-ROSS) satellite. With the second and final cancellation of N-ROSS more than a year ago, NSCAT has been proposed for flight on the Japanese Advanced Earth Observing Satellite (ADEOS). Primarily because NSCAT had not yet been selected for flight on ADEOS at the time of Congressional action on NASA's FY1989 budget, NSCAT funds were reduced to a level sufficient only for completing the sensor, essentially eliminating support for the ground data system and science team. Since that time, NSCAT has been selected for flight on ADEOS, contingent on the results of the Phase B studies and subsequent Japanese government approval of the ADEOS mission. Anticipating formal selection this August, the projected ADEOS launch date is early 1995.

This launch date will enable NSCAT to overlap the latter part of the flight of the TOPEX/POSEIDON mission, as well as the early part of NASA's Polar Orbiting Platform, which is proposed to carry a TOPEX/POSEIDON-class altimeter and an NSCAT-class (or better) scatterometer.

Included in the Phase B studies is a task to determine the feasibility of near-real-time access to NSCAT data for use by NOAA's National Meteorological Center, the European Center for Medium-range Weather Forecasting, and the Japanese Meteorological Agency.

COMPACT WIDE FIELD SENSOR (SeaWiFS). Based on the exceptional success attained with the visible/near-infrared radiometer--the Coastal Zone Color Scanner (CZCS)--which flew aboard Nimbus-7 and operated from 1978 until 1986, SeaWiFS has been designed to make improved observations of the near-surface concentration of phytoplankton pigments covering the global oceans, every two days with a four-kilometer spatial resolution, as well as covering selected local areas with one-kilometer resolution.

Phytoplankton are the base of the marine food chain; any variations in their productivity will propagate to higher order consumers, including fish and man. Uptake of carbon by the photosynthetic phytoplankton, and their subsequent sinking from near-surface waters that interact with the atmosphere, is a principal means by which the oceans serve as a sink for atmospheric carbon dioxide. On a local scale, phytoplankton concentrations respond to ocean pollutants in a manner which can be measured from space.

SeaWiFS was a proposed joint venture between the EOSAT Corporation and NASA that might have flown onboard Landsat-6 in 1991, with a design lifetime of five years. If approved, the joint venture would have taken the form of a "data purchase agreement", whereby NASA would provide funding in advance of Landsat-6 launch in an amount to match the incremental cost EOSAT would incur by developing SeaWiFS, integrating it onto the Landsat-6 satellite, and operating it. Under this arrangement, NASA and other Federal Agencies would have free access to the data for research and applications purposes, while EOSAT would have rights to sell the data for commercial and operational purposes. Unfortunately, the negotiations have just been terminated by EOSAT. NASA is now investigating other potential opportunities to obtain ocean color data.

Data from SeaWiFS are an important contributor to the Joint Global Ocean Flux Study (JGOFS), an international program to evaluate the role of the oceans in the global carbon cycle, and hence to understand future climate changes. JGOFS is a core program in the International Geosphere/Biosphere Program; partners include the US, Canada, the Netherlands, France, the Federal Republic of Germany, Great Britain, Japan, and Australia. A data system has been established at the Goddard Space Flight Center (GSFC) for the generation, archival, and distribution of CZCS products. At the present time, one-half of the eight-year set of CZCS data have been processed and archived and will be available on optical discs for use by the ocean science community. This data system will provide the basis for handling future ocean color data and products.

SPECIAL SENSOR MICROWAVE IMAGER (SSMI). Beginning in June 1987, the Defense Meteorological Satellite Program (DMSP) missions are carrying the SSMI, an improved version of the microwave radiometer which flew on Seasat and Nimbus-7. NASA utilizes SSMI data to generate, archive, and distribute sea-ice products working via the National Snow and Ice Data Center at the University of Colorado. A similar capability is planned for NODS at JPL to handle non-directional surface winds, rain rate, and atmospheric water vapor.

The SSMI products having a spatial resolution on the order of tens of kilometers are available globally on a daily basis. The sea-ice products, both fractional cover and first-year/multi-year fraction, are used in the detection of possible long-term trends in sea-ice cover associated with climate change. The other products noted above are used in computing the fluxes of energy across the air-sea interface.

GEODETIC SATELLITE (GEOSAT). Launched in March 1985 by the U.S. Navy, Geosat continues to provide information from its altimeter on the time-varying mesoscale component of the oceans circulation. In addition to better understanding the mesoscale circulation, the science community is finding the Geosat data particularly helpful in the development of analysis techniques use with the TOPEX/POSEIDON mission. Geosat also is providing information concerning the surface topography of substantial portions of the Greenland and Antarctic ice sheets; this will serve as baseline observations against which potential climate-related changes can be estimated.

ALASKA SAR FACILITY (ASF). Spaceborne synthetic aperture radar

(SAR), which was first flown on NASA's Seasat Mission, will be able to acquire radar images in all weather conditions with a spatial resolution on the order of ten meters and a swath width on the order of 100 kilometers. Principal features observable in SAR images include details of the sea-ice cover and its movement/deformation--important for air-sea heat exchange at high latitudes (which occurs in narrow leads unobservable by the coarse-resolution SSMI), surface characterization of glaciers and ice sheets--needed for studies of their mass balance and response to climate change, the length and direction of certain ocean waves--potentially useful for ship routing, and the detection of oil slicks--such as presently plague Alaskan waters.

SARs will operate aboard three foreign satellites early in the next decade: the European Space Agency's (ESA) first Earth Remote Sensing satellite (ERS-1) with a planned launch in late 199; Japan's first Earth Resources Satellite (JERS-1) with a planned launch in early 1992; and Canada's Radarsat with a planned launch in 1994. NASA has formal agreements with ESA and Japan regarding the reception of SAR observations at the ASF, which is in the process of being established at the University of Alaska in Fairbanks. An agreement-in-principle has been reached between NASA and the Canadian Space Agency whereby NASA proposes to provide a launch in exchange for the collection of and access to data from Radarsat; formal agreement is contingent on success with the budget process, in which NASA is seeking funds to cover the launch.

For each of these missions, a NOAA-provided near-real-time link between the ASF and their National Meteorological Center provides an opportunity for applications demonstrations in a more operationally oriented atmosphere.

Although data from the Shuttle Imaging Radar-C (SIR-C) will not be received at the ASF, experience gained through the flight of this SAR--in May 1992 and again in February 1993--will contribute to the experience base for exploiting data from these SAR missions.

Two major international research programs have been approved by the European Space Agency (ESA) to utilize data from ERS-1: (1) the Program for International Polar Ocean Research (PIPOR), involving more than 50 investigators from Europe, Canada, Japan, Australia, and the US; its main focus is to use the ERS-1 SAR to investigate Arctic and Antarctic sea ice and its interactions with the ocean and the atmosphere; and (2) the Polar Ice Sheet Program (PISP), involving more than 40 investigators from Europe, Japan, Australia, and the US; the goal of this program is to use data from the SAR, the altimeter, and the infrared radiometer aboard ERS-1 to map the surface characteristics of the Greenland and Antarctic ice sheets, to detect changes in volume of those ice masses, and to investigate why such changes are occurring. It is anticipated that similar international research collaborations will be established to make use of data from the JERS-1 and Radarsat missions.

ESA'S FIRST REMOTE SENSING SATELLITE (ERS-1). In addition to SAR, ERS-1 will carry an altimeter and scatterometer similar to, but less capable than, the TOPEX/POSEIDON and NSCAT sensors, as well as an improved infrared radiometer. ERS-1 currently lacks a global tracking capability so that data from the altimeter cannot be fully exploited. Access to these data by the U.S. research community is being discussed within ESA at the present time, and a favorable outcome is anticipated. In any event, a group of WOCE investigators and the NSCAT science team have proposed to ESA to use data from their altimeter and scatterometer, respectively; the proposals from both groups were selected by ESA. The analysis of resulting data sets, not only getting investigators "ready" for similar data from U.S. sensors, will go a long way toward addressing the needs of WOCE, TOGA, and similar experiments.

THE EARTH OBSERVING SYSTEM. The Earth Observing System (Eos) is a high priority candidate within the Office of Space Science and Applications for a proposed new start in the FY1991 budget consistent with our strategic plan (it has not yet been approved by the Agency or by the Administration). A number of facility class instruments and a number of Principal Investigator instruments were recently selected by NASA through an Announcement of Opportunity process which, when flown, would add significantly to ocean observations from space. Eos builds on and derives experience from the missions preceding it. The first

Eos payload complement is currently being planned for launch in late 1996, assuming a new start approval in the FY1991 budget, the NASA Polar Orbiting Platform under development as part of the Space Station Freedom, would carry a TOPEX/POSEIDON-class altimeter and tracking system, an NSCAT-class (or better) scatterometer, a Moderate Resolution Imaging Spectrometer (MODIS) which represents a significant improvement over SeaWiFS, CZCS, and AVHRR, and a microwave radiometer which would be a significant improvement over SSMI--combining imaging and sounding with improved resolution. In the late 1990's a second Eos platform is being examined to carry an advanced SAR system based on the SIR-C instrument; it would provide comprehensive measurements of sea ice and enable new studies of ocean surface manifestations of internal wave phenomena. The SIR-C would have been flown on the Space Shuttle a number of times before that time. These Eos instruments comprise the essential elements for measuring the global oceans from space. The international efforts being stimulated by the U.S. Eos mission plans would augment these observations by providing ocean color, surface temperature, altimeter, and scatterometer measurements from two additional polar orbiting platforms.

Eos and the companion meteorological satellites will offer oceanographers the opportunity to assess the heat and momentum flux across the air-sea interface, the response of the oceans to this forcing and their feedback to the atmosphere, the heat and nutrient transport by ocean currents, the changes in phytoplankton productivity, the formation and movement of sea ice, and the sensitivity of sea level to changes in ice-sheet volume. Moreover, the potential exists to assess the role of the oceans as a source/sink for carbon dioxide and other atmospheric gases.

Thank you for this opportunity; I will try to answer any questions you may have.

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MARINE AND FISHERIES COMMITTEE

STATEMENT OF

REAR ADMIRAL RICHARD F. PITTENGER, U.S. NAVY

OCEANOGRAPHER OF THE NAVY

BEFORE THE

SUBCOMMITTEE ON OCEANOGRAPHY

OF THE

HOUSE MERCHANT MARINE AND FISHERIES COMMITTEE

ON

SATELLITE OCEANOGRAPHY

27 APRIL 1989

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REAR ADMIRAL RICHARD F. PITTENGER

Oceanographer of the Navy (CNO OP-096)

A native of Nebraska, Rear Admiral Richard F. Pittenger grew up in Tacoma, Washington. He was commissioned an ensign in June 1958 after attending four years at the U. S. Naval Academy and was subsequently selected for the rank of Rear Admiral in 1984.

Following graduation from the U.S. Naval Academy he was assigned to USS DUPONT (DD 941) as Anti-Submarine Warfare (ASW) Officer and Torpedo Officer from 1958 to 1960. After leaving DUPONT he reported as ASW Officer on the commissioning crew and later served as Missile Officer on USS FARRAGUT (DLG 6) from 1960 to 1962. From 1962 to 1965, Rear Admiral Pittenger attended the Naval Postgraduate School in Monterey, California, where he earned a Master of Science degree in physics (underwater acoustics).

Upon completion of postgraduate studies, he served as Weapons Officer aboard USS RAMSEY (DEG 2). In 1967, he assumed command of USS PLEDGE (MSO 492). This was followed by a tour as Aide and Flag Lieutenant to Commander First Fleet. From 1969 to 1971, he served as Executive Officer aboard USS PERRY (DD 844). He reported to the Naval War College, Newport, Rhode Island as a student in 1971.

In 1972, Rear Admiral Pittenger assumed duties as Force ASW Officer for Commander Cruiser Destroyer Atlantic and in 1975 he became Surface ASW Officer on the newly formed Commander Naval Surface Force, U.S. Atlantic Fleet Staff. He subsequently served as Commanding Officer of USS CONNOLE (FF 1056). Following his tour on CONNOLE, Rear Admiral Pittenger reported to the Staff of the Chief of Naval Operations, serving a year term as the Head, ASW Branch, Surface Combat Systems Division (OP-353). He then served for two years as Commander Destroyer Squadron 26.

In 1984, Rear Admiral Pittenger became both Chief of Staff, U.S. Naval Forces, Europe, and Deputy U.S. Commander Eastern Atlantic, with headquarters in London.

In 1986, Rear Admiral Pittenger became Director, Antisubmarine Warfare Division, OP-71. He was permanently appointed to two star Rear Admiral on 1 October 1987.

In September 1988 Rear Admiral Pittenger became the Oceanographer of the Navy (OP-096).

He is married to the former Marjorie Andrade and has three daughters, Elizabeth, Margaret, and Katie and a son, John James.

Mr. Chairman and members of the Committee, I am Rear Admiral Richard Pittenger, Oceanographer of the Navy. I am pleased to be here this morning representing the U.S. Navy and I welcome the opportunity to comment on satellite oceanography. Satellite-based remote sensing of the oceans on a global scale provides the only means to observe and measure critical oceanographic information from areas in which our naval forces must be prepared to operate. The impact of this environment on our sensors and weapon systems will be a key factor in determining the ultimate success of the Navy's national defense mission.

The Navy must operate in unique and unforgiving environments. The sub-surface ocean extending from the sea floor to the air-ocean interface is complex in structure, difficult and expensive to measure, and yet vital for air, surface, and submarine naval forces to understand and predict. It also has very real effects on a range of non-military applications ranging from fisheries to resource management and pollution control. The atmosphere above the sea surface is poorly sampled over the world's oceans (in comparison to over land sampling), yet it too will affect mission safety and effectiveness. The air-sea interface, upon which a significant portion of our naval forces operate, challenges us to understand and capitalize upon both of these environments. Computer capabilities and model physics now allow us to simulate the ocean environment and predict its effect on our systems. Adequately defining the initial state of the global ocean environment for these computer models remains a challenge.

Measurements from ships buoys, and island stations are far too sparse to permit accurate model results. Space-based sensors, providing global coverage and frequent measurement updates, are the primary solution to this lack of data. As an example, satellite observations of the Gulf Stream are critical to the initialization of the dynamic ocean model in the region. However, satellite oceanography brings with it a set of new, unique and frequently expensive problems.

As a Nation, our steps in the past two decades have been slow but significant. Beginning in the 1970s, National Oceanic and Atmospheric Administration (NOAA) civilian weather satellites proved to meteorologists the value of watching the atmosphere from above. Significant advances were made in tropical weather forecasts and warnings, and Navy ships began to realize the benefits of these improved forecasts. Technology did not yet enable us to read the oceans from space.

In the late 1970's the SEASAT satellite broadened our thinking. SEASAT provided a measure of the surface winds over the global oceans using a wind scatterometer, it provided near photographic quality images of selected land, ocean and sea ice areas using a high-resolution synthetic aperture radar (SAR). It also provided us with a stunning view of deep ocean topography with its altimeter sensor. The NIMBUS satellite launched in 1978 provided ocean color images which allowed us to make determinations of ocean primary productivity, important for the fisheries industries. The Navy saw wind scatterometer data as a means of initializing global meteorological models, as well as determining some of the effects of this wind on the ocean, such as wind and wave noise and the wind driven movement of ice. SAR supplied detailed data about ice concentration, edges, types and age, as well as indications of the surface representation of phenomena such as ocean thermal fronts, wave spectra and internal waves. The significance of these data were greatly enhanced by the fact they were provided in an all-weather capacity. The sensors looked through cloud cover to the ocean surface. Navy's interest in satellites as a means of sensing the ocean was piqued, and even the disappointing loss of SEASAT after only 87 days on orbit did not dampen this enthusiasm.

Ocean fronts and eddies of cold or warm water are of great tactical significance to the Navy. Sound propagation through zones of temperature, salinity or density discontinuity is not uniform. Exploitation of this knowledge makes it possible for submarines and ships to remain undetected at ranges where detection would be expected if the ocean were not so complex. To not account for these features may prevent detection of an enemy while simultaneously rendering onboard weapons ineffective. Accurate sea surface temperature measurements are essential to this acoustics problem. Space-based sensors can provide the necessary global coverage, but currently have technological limitations which restrict high resolution measurements to cloud-free ocean regions. An all-weather sea surface temperature measurement capability is needed to support Navy operations which frequently occur in regions of high average cloud cover.

Navy's requirements for satellite based oceanographic data are derived directly from the needs of our deployed ships, submarines and aircraft. They must know the structure of the ocean in more detail than ever before, because quieter enemy threats in a noisier environmental background are difficult to detect. The ocean environment must be used in our favor. High latitude operations stress our detection systems even more with high winds and seas, and the effects of ice. Nearly constant cloud cover denies "clear-weather" remote sensing in these areas. The Navy's proposed/planned NROSS program of the early and mid 1980s was designed to meet these new challenges and requirements. It was to incorporate the proven SEASAT technology of a wind scatterometer with two new sensors; a radar altimeter for accurately measuring the actual height of the sea surface; and an all-weather sea surface temperature sensing sensor. While the requirements for these and other data were formally recognized by the Joint Chiefs of Staff in 1986 (MJCS 154-86), cost and technical design risk concerns coupled with real-world fiscal limitations caused NROSS to be terminated in 1988. Navy remote ocean sensing was challenged to find other less risky and more affordable ways to obtain the global data required.

There have been some outstanding success stories as well. In 1986 a small satellite called GEOSAT was launched carrying a radar altimeter similar to that planned for NROSS. The altimeter provides a precise all-weather measurement of the distance between the satellite and the sea surface. Precise information about the satellite's orbit allows determination of sea surface height, which is affected by sea floor topography as well as the density of the water. Information about wind speed based on the ocean surface roughness can also be calculated. GEOSAT was planned to have a 3-year on-orbit life. We are still receiving data from it today, and it appears this will last for several more years. Data from GEOSAT has been used by scientists worldwide in areas ranging from location of ocean fronts to global climate change effects on sea level. Additionally, the altimeter originally developed for NROSS has been upgraded for spaceflight and will be launched in 1990 in a demonstration of SPINSAT or Special Purpose INexpensive Satellite technology. The SPINSAT Altimeter will complement and eventually replace the GEOSAT at a fraction of its cost. The Office of Naval Research (ONR), Defense Advanced Research Projects Agency (DARPA) and Chief of Naval Operations (CNO-094) have teamed together for this project.

The Navy is also working with other services to utilize and coordinate with their investments in environmental remote sensing. Since the late 1960's the Air Force-administered Defense Meteorological Satellite Program (DMSP) has been providing secure, reliable and real-time meteorological support to the Navy, with data being received directly onboard the ships and stations supporting tactical operations. In the early 1980s, Navy funded the development of a new sensor called the Special

Sensor Microwave Imager (SSM/I) which measures sea ice, atmospheric moisture and wind speed under all-weather conditions. The prototype sensor was integrated onto an operational DMSP satellite in June of 1987 and has been providing valuable data in real time since launch. The SSM/I sensor programmed for NROSS has been turned over to the Air Force for use in a DMSP Block-5 satellite. All subsequent DMSP satellites, including the upgraded Block-6 series will have an improved version of this sensor, Special Sensor Microwave Imager/Sounder (SSMI/S), onboard satisfying joint Navy/Air Force requirements.

Some of the Navy oceanographic sensing requirements are currently and will continue to be met by the DMSP satellites, with the SSM/I sensor previously mentioned a good example. The Navy is actively participating in the DMSP "Block-6" concept studies which will provide guidelines for upgrading the existing series of DMSP satellites and may include requirements for specialized oceanographic sensors beginning about 2002.

Synthetic Aperture Radar (SAR) data, derived from SEASAT and from aircraft have proven valuable for accurately characterizing and locating sea ice in the Arctic. The Navy plans a continuing aircraft observation program utilizing SAR sensors in Arctic regions to enhance present operations and prepare for the use of future space-based SAR measurements.

The Navy recognizes a disturbing trend in the United States oceanographic satellite capabilities. With few exceptions, most of the new satellites and new sensors in the next decade will be operated by foreign organizations. The European ERS-1 and planned follow on ERS-2; the Japanese Advanced Earth Observation Satellite (ADEOS) and Maritime Observation Satellite (MOS) will be state of the art, sophisticated systems providing valuable new data to those who are authorized to receive it and willing to pay for it. The United States was unable to even find a spacecraft to fly one of the NROSS sensors, the NASA Scatterometer, or NSCAT, which NASA funded and built. Newer foreign satellites with active sensors (ones which emit a signal) have engineering constraints on when they can operate so that power may be conserved. Areas which are imaged will frequently not be ones which cover our requirements, thus our areas of high interest may go unmonitored. Political and cultural sensitivities within foreign governments frequently severely limit distribution of satellite data to other governments for military use. Direct reception of data from these satellites is also unlikely, making the data of less value for operational numerical models or local area applications.

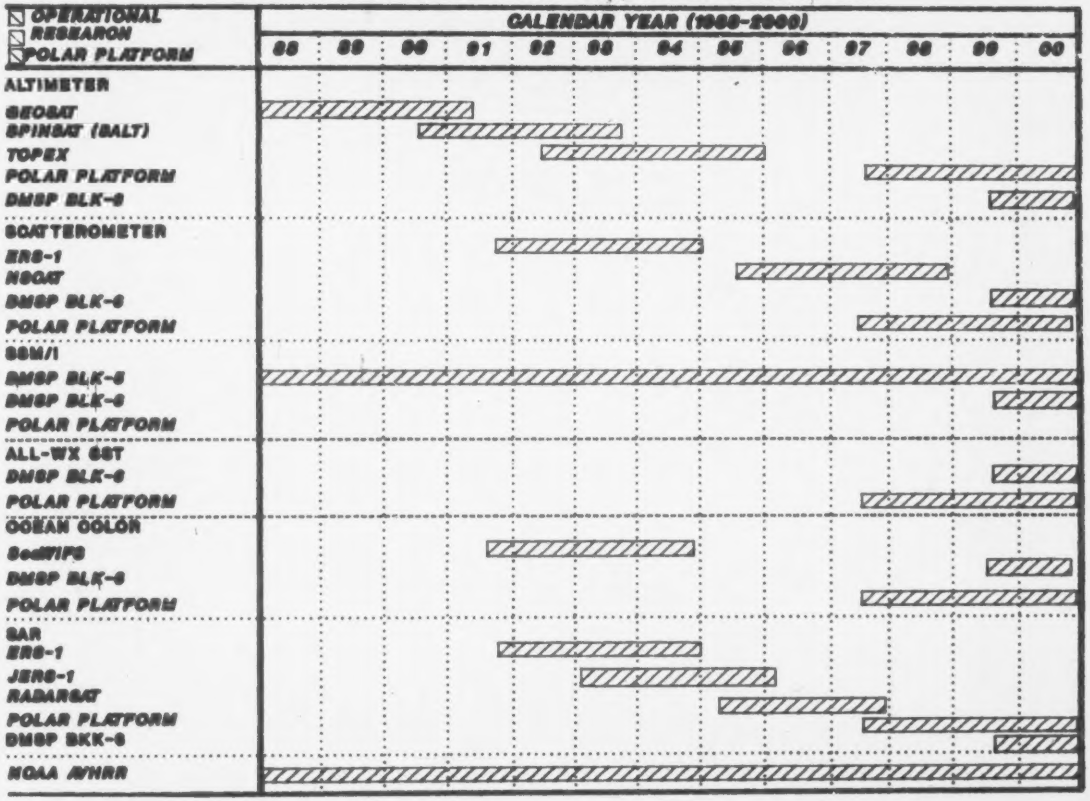
The next decade is the challenge facing the Navy and the Nation. Sensor and spacecraft technology for precise all-weather oceanographic sensing from space exists and will become better defined in the next 10 years (Figure 1.). A great deal of this technology was developed by the United States, yet we will soon have little control over the only operational sources of satellite remotely sensed oceanographic data. This will be especially true in the "all weather" sensor capabilities, so necessary to the Navy.

Data from earlier space sensors have opened a whole new awareness of the worlds oceans, but we have not been able to follow through with dedicated satellites for continuous, long term observations.

LIST OF ABBREVIATIONS:

GEOSAT - GEODETIC SATELLITE
SPINSAT - SPECIAL PURPOSE INEXPENSIVE SATELLITE
DMSP - DEFENSE METEOROLOGICAL SATELLITE PROGRAM
JERS - JAPANESE EARTH RESOURCES SATELLITE
SSM/I - SPECIAL SENSOR MICROWAVE IMAGER
SEAWIFS - SEA VIEWING, WIDE FIELD OF VIEW SENSOR
AVHRR - ADVANCED, VERY HIGH RESOLUTION RADIOMETER
ERS-1 - EARTH RESOURCES SATELLITE
SAR - SYNTHETIC APERTURE RADAR
NSCAT - NASA SCATTEROMETER
RADARSAT - RADAR SATELLITE

OCEANOGRAPHIC SATELLITE REMOTELY SENSED DATA



TESTIMONY OF

DR. ROBERT W. CORELL
ASSISTANT DIRECTOR FOR GEOSCIENCES
NATIONAL SCIENCE FOUNDATION

BEFORE THE
SUBCOMMITTEE ON OCEANOGRAPHY AND THE GREAT LAKES
COMMITTEE ON MERCHANT MARINE AND FISHERIES
HOUSE OF REPRESENTATIVES

APRIL 27, 1989

Mr. Chairman, thank you for the opportunity to testify on the subject of satellite oceanography on behalf of the National Science Foundation.

The Earth's environment is a dynamic system that changes on all time and space scales. Although there is much uncertainty about their relative contributions, both natural phenomena and human activities may be influencing these changes. It is vital that a scientific understanding of the Earth system be obtained on a global scale by describing how the environment's component parts and their interactions have evolved, and how they may be expected to evolve in the future on all time and space scales.

Specifically, the immediate challenge is to understand the basic mechanisms and interactions and ultimately develop the capability to predict natural environmental changes and to see if there are others which may be influenced by man. As you may know, the interagency Committee on Earth Sciences (CES), has established the U.S. Global Change Research Program (USGCRP), specifically designed to improve the scientific basis for policymaking related to global change issues. This Program was outlined in a report entitled, "Our Changing Planet: A U.S. Strategy for Global Change Research," which accompanied the FY 1990 Budget. The CES will continue to ensure that a well coordinated and effective research effort is maintained. In fact, one of the principal Program objectives is to establish an integrated and comprehensive monitoring program for Earth system measurements on a global scale. Clearly, satellite sensors are an important element of this objective.

In 1985, the National Science Foundation first formulated its new thrust in Global Geosciences, which became a reality in FY 1987 as a new initiative. Independently, other federal agencies, as well as national and international scientific organizations were developing similar programs. At the heart of this tremendous scientific renaissance of the environmental biogeosciences was the great excitement which had been generated as a product of the U.S. Space Program.

Not only were there the great color photographs which enabled us to look at the globe as a complex integrated whole, but there were also the magnificently comprehensive yet detailed products of the first satellite sensors. These were particularly inspiring to oceanographers, who saw for instance, instead of single tracks of data rarely repeated across vast tracts of ocean, details of small currents and eddies along the whole course of the ever-changing Gulf Stream as revealed by sea surface temperature on time scales of days to years. They could also see regions of intense biological productivity through sea surface color, and often dynamical linkages between the two. The term "satellite oceanography" is today firmly entrenched in the lexicon of the discipline.

These new insights, and the accumulating evidence of disquieting global trends most often centered around potential global warming and the "greenhouse effect", combined in the minds of many scientists to form the seeds of the now familiar suite of programs which together comprise global change research.

As you know, the National Science Foundation does not undertake research activities but rather supports those of the U.S. academic community. In the case of the ocean sciences, our mission in this regard is very substantial, since we provide the support for approximately 65% of all U.S. academic ocean science research, including over 70% of the support of the U.S. academic research fleet. We regard our role as primarily "ground-based", which does not include support for the design, construction, launch or operation of satellite sensors, nor capture of transmitted raw data. We do, however, see our role very much as one of supporting the research applications of these products within the academic community, and are convinced of the increasing significance of satellite-derived data in the future of oceanography, particularly in the context of Global Change research.

GLOBAL CHANGE RESEARCH

The National Science Foundation has been a major player in facilitating the planning and implementation of Global Change research. These efforts have been in response to the urgings of the U.S. academic research community. It is necessary to provide a brief overview of the research required to improve our knowledge of Global Change, to describe some recent research findings, and to point out the roles of satellite sensors.

Much of the recent public interest in global change has focused on greenhouse gas accumulation and associated threat of warming. While there is much yet to learn, research is providing an understanding of several aspects of the greenhouse effect. Some things are known with high certainty; many remain very poorly understood. We have all heard much about the prospects of a potential doubling of carbon dioxide in the next century or so. It is clear that atmospheric abundance of carbon dioxide is increasing, due to both natural processes and human activities.

The future rate of increase will depend strongly on (i) technical developments, economic factors, and policy decisions, which will be difficult to predict, (ii) the net uptake of carbon dioxide by vegetation and the oceans, about which scientific understanding is still uncertain, and (iii) the net effect of interactions among all elements of the earth systems, including potential feedback responses. Nevertheless, scientists are increasingly in agreement that a doubling of carbon dioxide abundance is likely to occur within the next century. Other greenhouse gases, such as methane, chlorofluorocarbons (CFC's), ozone in the lower atmosphere, and nitrous oxide are also on the increase.

We are just now beginning to understand that one of the major sources of cloud condensation nuclei over the ocean appears to be dimethylsulphide (DMS). DMS is produced by phytoplankton in sea water and oxidizes in the atmosphere to form a sulphate aerosol. Because the reflectance of clouds of these condensation nuclei, biological factors in the ocean can contribute significantly to the regulation of climate. Introducing such complex processes, of which this is just an example, into our computer models should increase our capacity to begin to predict more credibly the global temperature trends due to greenhouse gases.

THE OCEAN-RELATED SATELLITES

There are several ocean-related satellite missions which are either operational or projected for the near future that are very important for ocean sciences global change programs. The NOAA ongoing series provides the all-important sea surface temperatures, important not only for heat flux studies but also for the recognition of ocean features such as currents, eddies and fronts. It also provides information on sea ice cover. The US Navy GEOSAT radar altimeter currently provides sea surface height, wave height and wind speed, which are used to identify ocean eddies and other features. Its replacement (SPINSAT) is due to be operating by Spring 1990, and should hopefully provide an uninterrupted data stream.

Approved missions include several important ocean-related satellite sensors. TOPEX/POSEIDON (NASA/CNES) due for launch in 1992, will provide precise altimetry for ocean currents. The E ERS-1 satellite (ESA), to be launched at the end of 1990, will have both altimetry and a synthetic aperture radar scatterometer. The U.S. Alaskan SAR facility will capture and provide this data, which will be vital for polar ocean and ice properties. ADEOS (Japan/NASA) will carry the U.S. NSCAT, for accurate wind speed and direction, which should provide an essential overlap with

TOPEX. It is also scheduled to carry a color scanner (Japan) which will provide information on ocean surface phytoplankton concentrations, and by extrapolation, primary biological production.

Provision of ocean color information since CZCS failed on NIMBUS 7 in 1985 has been an ongoing concern to academic oceanographers. Besides its primary function, it has shown itself useful in interpreting ocean surface structure, in much the same way as sea surface temperature has, particularly in lower latitudes in summer, where temperature differentials are too small. NASA is continuing to negotiate with EOSAT to include the SeaWIFS color scanner on LANDSAT 6 in 1991.

Academic ocean scientists have increasingly become accustomed to using the products of ocean-related satellite sensors over the last decade. Many regard them as much an indispensible source of information as that derived from ships at sea. This applies to individual researchers engaged in projects relatively independent of the major global change programs as well to those involved in TOGA, WOCE, GOFS, GLOBEC, LMER and ARCSS. These global change programs, which are in different stages of planning and implementation, are described briefly below.

NSF INVOLVEMENT IN GLOBAL CHANGE PROGRAMS

TOGA: The international study of interannual variability in the Tropical Ocean and the Global Atmosphere (TOGA) is the most advanced program, approaching its fifth year in the field. NOAA has the lead agency responsibility and NSF contributes to its support. Major advances in our understanding of the relationship between the El Nino and the Southern Oscillation (ENSO) and its climate implications have been made. We have improved substantially our understanding of the processes that control the heat balance in the equatorial central Pacific, particularly the maintenance and long-term variability of the eastern "cold tongue" and the western "warm pool". Further, we know much more about the oceanic currents in this critical region, which in turn is enhancing our knowledge of the total ENSO process. Sea surface temperature sensing continues to be vital in this program, as does other satellite-derived data on ocean structure.

WOCE: The World Ocean Circulation Experiment is the largest coherent oceanographic experiment ever contemplated. It is directed to acquiring an understanding of the world oceans through their full depth, which is essential to the successful simulation of the broad evolution of global climate beyond a few years. The major field observational period for WOCE will begin in 1991 and extend over a period of about eight years. A central part of the strategy for the global description of the ocean is satellite altimetry, in addition to the routine data provided by meteorological satellites. There is also a need for a gravity mission to produce a geoid on scales down to 100 m. No such mission is currently scheduled, but adequate designs exist. There is no requirement for simultaneous determination with other measurements, only that it should fly within the 1990s.

GOFS: The Global Ocean Flux Studies and the international counterpart J(joint)GOFS are a planned sequence of scientific investigations of oceanic biogenic cycles, and their role in modulating global change. Research focusses on a complicated set of physical, chemical and biological processes governing the production and fate of biogenic material in the ocean. The central measurement is the accurate estimation of global scale production of biogenic material in the ocean. The most important satellite sensor therefore is a color scanner, although information on physical ocean structure is also very relevant. Although the color sensor is not vital to specific field experiments, because aircraft-mounted sensors can, and are, currently being utilized, the extrapolation of basin-scale experiments to long-term global models is dependent on synoptic global scale data from a satellite color sensor.

ARCSS: Arctic Systems Science is a new NSF program in its early planning stages which will focus on the role of the Arctic in global change. One component of relevance here is Ocean/Atmosphere Interactions, which concerns the air/sea interactions involved in the evolution of marginal ice edges and polynyas, biological production, ecosystem dynamics and transport and deposition of biogenic carbon, and the formation of saline deep water--in short the role of the Arctic ocean and atmosphere in controlling global change. Satellite sensors for determining sea ice formation and extent, surface ocean physical structure and ocean color will be important in these regions, where shipborne sampling and surveying technology becomes so much more difficult to implement.

GLOBAL ECOSYSTEMS DYNAMICS: There are two Global Ecosystems Dynamics programs which are also in the early stages of planning and implementation. These are Land Margin Ecosystems Research (LMER) and Global Ocean Ecosystems Dynamics (GLOBEC). Their focus is the study of ecosystems dynamics under the influence of global change, including sea level rise, atmospheric and ocean warming, changes in incident radiation and anthropogenic pollutants. LMER focusses on the coastal wetlands, estuaries and nearshore regions likely to be most quickly impacted, while GLOBEC, still in its early planning stages, views ocean ecosystems at large, and the physical control of interannual to decadal variability of living resources. Estimation of synoptic large areal scales of primary production for both coastal terrestrial vegetation and ocean surface waters would make heavy use of satellite-based color sensing when available.

CONCLUSION

The rate of development of these new programs, as with the rate of development of the new generation of ocean satellite sensors, has never been so rigidly fixed that serious mismatch has been considered a potential fatal flaw in any particular case. In fact, the early optimistic timetables for sensor deployment as well as observational and experimental field programs have both slipped for a variety of reasons. Nevertheless, it must be stated unequivocally that without the ocean satellite sensors, the rate of progress of the global programs will necessarily be severely restricted. The volume and density of data would be limited to the point that the sensitivity of predictive models would be inevitably reduced, and the resulting projections of the consequences of global change would be less reliable.

Satellites and Oceanography: Prospects and Problems

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1 Introduction

The ocean is a global fluid and satellites are the only means known permitting observations of the entire system. They are thus central to all the oceanographic programs that have been planned for the 1990's directed at understanding climate and global change more generally.

Among these programs are the World Ocean Circulation Experiment (WOCE), the Joint Global Ocean Flux Experiment (JGOFS), the Tropical Ocean - Global Atmosphere Experiment (TOGA), Global Energy and Water Cycle Experiment (GEWEX) and several others. The programs are the focus of the scientific community's efforts to come to grips with present uncertainties over climate change, greenhouse gas effects, and global environmental change generally. They represent over a decade of hard planning efforts and are in part already in progress.

2 Major Requirements

Shipborne measurements remain a necessary central component of all oceanographic understanding - because they are the only way to understand what is happening below the surface. Spacecraft measure only phenomena manifested at the seasurface. Unfortunately, ships are very slow and very expensive and can never provide large-scale continuing coverage. But large-scale, continuing coverage is precisely what spacecraft do best. Thus the requirements for, and the specific planning for, oceanographic measurements from space is a complex and delicate weighting of what can and must be space-based, with those things which can and must be done from ships and unmanned instrumentation. The measurements are complementary to each other; both types are essential.

From 15 years of discussion and planning, there is a consensus concerning the central spaceborne requirements for understanding global change. These are:

(1) Altimetric measurements for measuring the shape of the seasurface through time and space; these measurements are the oceanographic equivalent of the meteorologists' global barometer network.

(2) Scatterometers for determination of the wind field over the ocean; there is no other way to do it.

(3) Color observations for calculation of the oceanic biological productivity and its changes.

(4) A gravity mission so that the altimetric measurements can be used to directly compute absolute oceanic motions from the altimeters.

There are requirements in the short term for all of these measurements as research tools. In the longer term, scientists agree that there must be operational observations of this type - global change and climate change are problems that will be with us for decades and it is inconceivable that we will understand what the planet is doing without an ongoing program for observation and general monitoring.

3 Prospects and Problems

There is no Federal agency responsible for ongoing measurement and understanding of the ocean. Thus the fact that there are some useful spacecraft expected to materialize is the result of 15 years of hard work by a few people who had a lot of patience and foresight, and a fair bit of good luck, in an essentially chaotic situation. The US government has no coherent policy for this type of science, and one has a clear impression of decision-making at random and by accident. (Decision-making within the Navy with regard to NSCAT and the completely independent course for the GEOSAT altimetric satellite is one especially clear example of the lack of any coherent policy.)

The programs already alluded to demand overlap of the spacecraft measurements with the planned in situ measurements (because of their complementarity) and many of the spacecraft measurements need to be simultaneous to extract the maximum scientific benefits.

The present situation, to my knowledge, is as follows:

The US and France will together fly a special altimetric mission called TOPEX/POSEIDON, possibly in 1992 and running for (nominally) three years.

The European Space Agency will fly a spacecraft called ERS-1, carrying an altimeter and a rudimentary wind-measuring scatterometer possibly in early 1991 also nominally operating for three years.

TOPEX/POSEIDON has been subject to large annual budget cuts by NASA and Congress leading to several postponements and cost increases. All Agency reserves for this program have been exhausted. No further delays or unexpected difficulties can be accommodated. Should there be any further delays, a large internationally coordinated set of programs in WOCE and JGOFS involving ships and in situ instrumentation will be seriously disrupted (these schedules are made years in advance) threatening major scientific goals.

ERS-1 is being flown for non-scientific purposes and the scientific community is experiencing difficulties in making its interests felt in details of the mission configuration. US agencies lack resources adequate to fund scientific investigators to use the data from ERS-1, assuming that it is made available to us. Nonetheless, we are optimistic that this program is on track and will be scientifically productive (US involvement is peripheral, however. ERS-1 is symbolic of the US concession of its clear leadership in satellite oceanography as shown in GEOS-3 and SEASAT.)

There are several other potential missions of major importance to the global change problem. These include the Sea-WiFS (color scanner) intended to fly on LANDSAT 6. This NASA-supplied instrument is being held hostage to the current turmoil concerning The Eosat Corp. and the LANDSAT series generally. Those directly involved are finding it increasingly difficult to perceive a positive outcome; the JGOFS goals will be seriously jeopardized if this instrument does not materialize during the WOCE/JGOFS time period.

A NASA-constructed wind-measuring scatterometer (called NSCAT) was intended to fly on the Navy's NROSS in the same time period as TOPEX/POSEIDON. Although approved by Congress, the Navy was unable to construct internally a coherent long-term strategy for measurements from space, and unilaterally and without warning cancelled NROSS. In the great uncertainty existing in the aftermath of the Navy decision, Congress cut the NSCAT budget to the point of near-extinction. The program was kept alive in part by cannibalizing TOPEX/POSEIDON - thus in turn jeopardizing that program. NASA and the US scientific community have now been reduced to supplicants of the Japanese to carry NSCAT on a possible Japanese spacecraft circa 1995. Thus the possibility of NSCAT contributing directly to the major oceanographic programs of the early 1990's has disappeared.

No gravity measuring mission, although it is agreed to be technically feasible, has ever advanced even close to the mission approval stage. Such a mission would greatly increase the scientific return from the altimetric satellites.

The Navy is now flying GEOSAT, a lower quality altimetric satellite, and is preparing to launch a follow-on; much of scientific use is being learned from this spacecraft. But little or no coordination exists between decisions taken on these spacecraft and the on-going oceanographic programs outside the military. Whatever the final fruits of these missions for oceanography, the decision-making process which has led to them leaves little confidence that other than narrowly perceived parochial interests were considered.

Assuming the color scanner is flown, and that TOPEX/POSEIDON and ERS-1 fly without mishap (note there are *no backups* for either mission - a "cost saving" measure) the oceanographic community will meet many of the scientific goals of the major global change programs of the early 1990's. A gravity mission can be flown anytime within the 1990's and still meet the major scientific demands. (It is worth noting that a number of ongoing instruments on the two meteorological series (NOAA and DoD) including AVHRR (sea surface temperature) and SSM/I are of interest and use. A complete listing of all known ocean-related spacecraft is attached. This table was compiled for me by the Joint Oceanographic Institutions. Most of the spacecraft listed are not oceanographic satellites, but make a measurement of some quantity of interest to oceanographers, albeit in some cases its importance is slight.) The major gap in the next five years is that left by the absence of a US wind measuring capability.

That we are in a partially favorable situation (although far from ideal or from what could have been done) is in large measure fortuitous. That several missions are coming to fruition at more or less the same time in conjunction with field programs able to complement them is in part luck, and part the result of arduous campaigning by the scientific community and the notable devotion of a few individuals within the government agencies.

4 The Future

It is difficult to be very optimistic about the period following the coming generation of spacecraft. The current programs, including spacecraft plus in situ observational systems, are the result of a complex coalition of US and foreign scientists from private institutions and universities working largely independently of any focussed governmental efforts. Again, with some notable individual exceptions, Federal agencies have not been very conspicuous. Major US oceanographic funding comes from the National Science Foundation, and to a lesser degree from the Office of Naval Research. NASA is responsible for experimental spacecraft developments and research, not for operational measurements. Both the NSF and ONR fund scientists on a 1-3 year basis, whereas global change programs must be formulated and sustained on much longer time-scales. Who is responsible for assuring that the US will properly observe the global ocean from space and from within over the long-term? It appears that no one is. (Many outsiders think that NOAA plays this role; it does not.)

What do we need? We need a governmental policy leading to clear lines of responsibility, and adequate resources, for sustaining global oceanographic observations through a sensible partnership of the various government agencies involved. The observations include, but are not restricted to, the spaceborne ones. Spaceborne observations do require particular attention because of the very long-lead times involved, the complex technical issues, and the extraordinarily complicated political issues that seem always to surround them. The current plans of NASA focussed on the Earth Observing System are very unlikely to prove an appropriate long-term solution. The clear lesson of the last 20 years of the US space program is that claims EOS will fly when needed, circa 1995, are fantasy - propagated for political reasons. This time period is a very important one - we will have the beginnings of global observational series begun in the early 1990's; CO-2 and other effects should start becoming much more obvious about that time. It is difficult to view with equanimity the probability that just then the US will be without any serious observational capability.

Furthermore, even if by some miracle such a schedule could be met by EOS, all our experience suggests that single, monolithic approaches to complex scientific problems are ultimately poor ones. The different types of measurement listed above each demands a spacecraft in different orbits, maneuvered differently and with entirely different data flows. To some extent, one measurement jeopardizes the success of another if carried out on the same platform (e.g. the large antennas for scatterometry degrade the altimetric measurements). Furthermore, the technology necessary for measurements in space is evolving rapidly. Large complex spacecraft place artificial constraints on the ability to innovate technologically and stretch inordinately the timescale for improvements.

We need a sequence of "earth explorers", small, inexpensive special purpose spacecraft which could be flown in an ongoing program of combined engineering development and continuous, indefinite ocean monitoring (somewhat like the continuing series of meteorological spacecraft).

In the long-term there must be some coherent and penetrable government policy concerned with oceanic measurement and understanding as a combined scientific-long-term monitoring problem. Spacecraft must play a central, but not the only role. Different government agencies have different needs, perceptions and problems; but at the present time, the US effort directed at understanding global change through space-based observations of the ocean is clearly much less than the sum of its parts.

The current "global change" interest is of course, highly welcome in general terms. But climate and global change are long term problems that history suggests will wax and wane in public and Congressional attention. To really answer the questions which press on us will require many years and decades of hard, often unglamorous work, directed at unravelling many complex and subtle scientific and technical issues. There is a grave danger that the urgency and attention being lavished on these problems will lead to inappropriate reorganizations, program plans, and hardware ill-suited to the long term.

DRAFT FACT/BRIEFING SHEET Joint Oceanographic Institutions, Inc. 4/12/89

Satellite	Sponsor	Ocean-related Sensor	Launch	Science Impact	Remarks
CURRENT/NEAR TERM & OPERATIONAL OCEAN-RELATED MISSIONS					
NOAA Series	NOAA	AVHRR	ongoing series	Sea surface temperatures, ice & snow cover	Used in both ocean feature & heat flux studies,sea ice. Cloud interference.
GEOSAT	USN	Radar altimeter	3/85	Sea surface height, wave height, wind speed (only), ocean eddies & features	Now in extended Exact Repeat Mission.
"GEOSAT-2" SALT	USN	Radar altimeter (NROSS altimeter on Spinsat*)	spring 1990 (contract signed)	Sea surface height,wave height, wind speed (only), ocean eddies & features *Special purpose inexpensive satellite	If NROSS ALT overlaps with GEOSAT then initial approach to synoptic measurement.
MOS-1	Japan	Visible & IR scanner	2/87	No storage (in sight use only), technical demo	Only 4 spectral bands. Limited oceanographic utility.
DMSP Block 5	USAF	Microwave radiometer (SSM/I)	6/87	Ice, waves, humidity, rain, wind speed (only)	New sensor. NASA data facility with NSIDC.
SPOT-1	CNES	Visible & IR radiometers	2/86	Nearshore feature tracking, sea ice	Visualization of nearshore ocean/ice features. To be followed by SPOT-2.
LANDSAT 4/5	EOSAT	Visible band radiometer	series	Nearshore feature tracking, Sea ice	4/5 need to be followed by LANDSAT 6.
APPROVED OCEAN-RELATED MISSIONS					
E ERS-1	ESA	ALT, SCAT/SAR, Microwave & visible radiometers	10/90	US Alaska SAR Facility for polar oceanography, ocean and ice properties	First SAR/scatterometer mission since SEASAT.
TOPEX/ POSEIDON	NASA/ CNES	ALT, GPS & laser tracking	1992	Precise altimetry for ocean currents	Basis for WOCE.
MOS-1B	Japan	Color scanner, IR microwave radiometer	1990	Technical demo	Follow-on to MOS-1. Limited oceanographic utility.
J ERS-1	Japan	SAR, Radiometer	1992	Synthetic Aperture Radar, ice, leads	Polar oceanography, Alaska SAR Facility.
RADARSAT	Canada/ US	SAR	1994	Synthetic Aperture Radar, ice, leads	Polar oceanography, Alaska SAR Facility.
ADEOS	Japan/ NASA	US NSCAT, Color scanner	1995	Accurate wind speed & direction, primary production	NSCAT to overlap with latter part of TOPEX for WOCE & early stage of POP-1.
FUTURE OCEAN-RELATED MISSIONS					
LANDSAT 6	EOSAT	SeaWIFS? (color scanner)	1991	Essential color scanner to reduce gap left by CZCS failed (1986) NIMBUS 7	Ocean color. SeaWIFS status questionable - may not fly. NASA supported instrument essential for JGOFS.
Polar Platforms POP - 1,2 European P Japanese P	 NASA ESA Japan	Various, exact payloads not yet finally selected	1996-7 through 1998-9	POP-1: Full suite of ocean sensors proposed include ALT, SCAT, color scanner & microwave radiometer	POP-1 First element of NASA EOS program. New start for NASA in FY 1991.
DMSP Block 6	USAF	SSMI, SCAT?, ALT?	2000?	Ocean & ice properties	Opportunity for Navy to establish operational ocean requirements.

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STATEMENT

of

The National Ocean Industries Association

on

The Benefits of an Operational Oceanographic Satellite

before the

Subcommittee on Oceanography and the Great Lakes

House Merchant Marine and Fisheries Committee

April 27, 1989

Washington, D.C.

NOIA is a national trade association based in Washington, D.C. Most members are private companies engaged in providing services, supplies, and support capabilities involving marine or offshore manufacturing, or oil and gas development. NOIA members share the philosophy that private enterprise development of offshore resources - consistent with sound environmental practices and safeguards - is vital to our nation. These companies are located in more than 30 states and the District of Columbia.

It is NOIA's position that we have the technology to provide the general public, and the maritime industries, with improved marine weather forecasting through satellite oceanography. We urge Congress to take the steps necessary to make the technology operational in order that the public may benefit from it.

A discussion of the role of satellite information in current and projected use by the ocean industries, as well as the benefits of an applied operational oceanographic satellite capability, must include a brief review of the history of satellite oceanography. In 1978, NASA developed and demonstrated the technologies which would significantly improve offshore and Great Lakes safety for maritime activity through the space system SEASAT. SEASAT provided remote mapping of sea state (wave height), sea surface winds (storm intensity) and currents. However, since 1978 this knowledge has not been utilized operationally to increase the marine and coastline safety. Thus, we have the means to provide severe weather information but we have not proceeded to take advantage of our own technology. Both Europe and Japan have employed this U.S. developed technology to the benefit of their respective citizens and marine interests.

NOIA has studied the impact of operational applications of this technology and found the safety of a large segment of the population, as well as the productivity and safety of domestic maritime industries, would be significantly improved. Our studies, using 1987 Search and Rescue Statistics of the U.S.Coast Guard, show:

- 75% of the U.S. population have coastal or Great Lakes access. This encompasses 30 of the 50 states.
- Almost 10 million recreational boats are in current use in this country.
- 40,092 recreational boats required assistance by the Coast Guard in 1987; a significant number of these were weather related emergencies.
- 1,585 lives were lost.
- $460 million in property was lost.

Current satellite technology is capable of supplying most of the information necessary to greatly improve operations. Better baseline data on the environment would facilitate major savings in the offshore activity of all maritime industries. Surface weather can be accurately observed, including wave height and direction, wind force and direction, sea surface temperatures, and other basic information necessary to identify the location of ocean currents.

NOIA member companies strongly support an operational oceanographic satellite data system. In fact, the association has received numerous letters of support for such a program of applied technology. These supportive industries include those involved in shipping, marine construction, offshore exploration and production, and aviation. The most illustrative letter received described the near-catastrophic loss of the QE II oceanliner in September, 1978. Over 2,000 lives might have been lost in a severe North Atlantic storm. Fortunately, the ship and passengers survived. Analyses of SEASAT data has shown that the resulting improvement in forecasts of wind and wave patterns achieved by using SEASAT data could have prevented this near-disaster and makes obvious the fact that an operational oceanographic satellite will save lives, cargo, and ships.

NOIA recognizes the difference between the civil space charters of National Aeronautic and Space Administration and the National Oceanic and Atmospheric Administration. The Department of Commerce, specifically NOAA, has the mission for civil operational remote sensing satellites. However, this operational counterpart to NASA's research programs has never been funded. The problem is one of relative priorities between technology development and the operational applications of this technology.

In the FY89 budget, one can easily see the relative priorities. The total civilian space budget was approximately $10.7 billion. 96% went to NASA for research programs; less than 4% went to NOAA for civil operational space systems. This amount allocated to NOAA was inadequate to support an operational oceanographic satellite program.

Therefore, NOIA recommends the following:

- Increase the percentage of civil space budget for operational applications vs. technology development.
- These reapportioned funds for civil operational satellites should be provided to NOAA along with specific directions from the Congress to develop a civil operational ocean sensing satellite capability by the turn of the century. This capability must include:
    1) Mapping of sea surface wind speed and direction
    2) Measuring sea state
    3) Mapping ocean currents

In conclusion, NOIA urges the subcommittee to work with other members of Congress to appropriate funding for an operational satellite program in the near future. The United States must look to its future ocean sensing needs and begin today the lengthy process of implementing a solid program of development of operational capabilities.

Statement Of
The National Fisheries Institute

On
Satellite Oceanography

Before The

Subcommittee on Oceanography and the Great Lakes
April 27, 1989

Thank you for this opportunity to testify on the importance of satellite oceanography to the U.S. fish and seafood industry. My name is Richard E. Gutting, Jr. and I am Vice President--Government Relations for the National Fisheries Institute. The Institute is a trade association representing the fish and seafood industry with over 1,000 member companies located throughout the United States. Our members are engaged in all aspects of the industry including harvesting, processing and marketing.

Variations in ocean conditions play a vital role in U.S. fisheries. Monitoring these changes from spacecraft sensors offers the combined advantages of large scale synopticity, high spatial resolution and frequent coverage. Past successes in the use of satellite data in developing and managing our fisheries suggest that present programs be expanded. We urge the Subcommittee to support such an expansion.

Many fish are temperature-sensitive, and knowledge of water temperature can be helpful in locating them. Salmon and tuna, for example, feed on bait fish which congregate in upwelling areas, with salmon on the cooler, nearshore side and albacore on the warmer, offshore side. These thermal boundaries, or "edges," show up on satellite images. Ocean temperature measurements made from polar-orbiting and geostationary weather satellites operated by the National Oceanic and Atmospheric Administration (NOAA) have been used in these fisheries for over a decade. Wind direction and force, sea swell, height and direction, and current set and speed are important factors in determining whether fishing can occur in many areas. All of these conditions can be detected by satellite.

Perhaps the most important satellite measurement used in fisheries was ocean color from the Coastal Zone Color Scanner (CZCS) that operated on the National Aeronautical and Space Administration (NASA) Nimbus-7 satellite. Unfortunately, that sensor has been inoperative since about mid-1985 and there has been no replacement sensor launched. Case studies have also demonstrated that ocean color measurements can help define productive fishing areas, predict fish recruitment and improve forecasts of sea and weather conditions.

The commercial tuna vessels in the eastern North Pacific Ocean regularly use satellite-derived ocean temperature charts to locate fishing areas. Other commercial tuna vessels use ocean temperature information measured by satellite when information is available, including those operating in the eastern tropical Pacific, the Gulf of Mexico and along the Atlantic coast.

Satellite-derived ocean temperature information is used by salmon fishermen in the Pacific northwest and by swordfish and shark fishermen. Gulf of Mexico shrimp, butterfish and menhaden fishermen have used satellite information when it was available, as have lobster, menhaden, red crab and groundfish fishermen along the Atlantic seaboard. An increasing number of recreational fishermen are using satellite temperature charts to locate favorable places to fish in coastal waters all around the U.S. seaboard.

Satellite data can help vessels save fuel and time. Although no rigorous analysis has been done to evaluate the value of remote sensing to fishing vessels, some studies show that satellite information can save about 25-30 percent, and in some cases, up to 50 percent in search time. This savings is especially important where there are catch quotas or similar fishing restrictions. It allows fishermen to reduce costs, thereby improving their economic yield, lowering costs to consumers and improving their competitive position in global markets. Satellite information also tends to spread fishing fleets out. Without data, vessels know only those areas that others have happended upon. This concentrates fishing pressure on a few schools which can be detrimental.

Satellite remote sensing also can provide valuable information to fishery managers. For example, spawning areas of some species can be defined using ocean temperature and color data from satellites. Satellite data also can be used to improve understanding of fish recruitment. This type of information can help to make catch allocations more precise, ensuring the long-term health of fish populations. It also may be possible to use satellite ocean temperature and color data to adjust the timing of the release of young salmon from hatcheries, so that their arrival in ocean waters will coincide with conditions favorable for survival. Even a few percent reduction in the mortality of young salmon, which is about 95-98 percent, could result in significantly greater harvests.

These experiences suggest that ocean remote sensing should move ahead vigorously. Yet this is not occurring. Although the U.S. space program has new and exciting goals, ocean remote sensing has lost momentum and is losing ground. Operational sensors designed to meet the needs of the fisheries appear unlikely in the foreseeable future.

While the U.S. has been moving backward, other countries have not. Japan and France have established information centers that prepare and disseminate satellite-derived ocean products to fishermen using satellite data obtained from U.S. polar-orbiting weather satellites. Japan and France also are expanding their capabilities with the launch of their own ocean sensors. Other countries presently are, or soon will be, using data from U.S. satellites to support fishing operations, including Australia, Taiwan, Portugal and several developing nations. The Soviet Union and other eastern bloc countries also use satellite remote sensing in their fisheries.

The U.S. ocean remote sensing program is in danger of losing its leadership position, not because of technical difficulties, but because of policy and institutional failures. One example is the division of the U.S. remote sensing program within the federal government. NOAA has concentrated its attention on operational earth remote sensing and has allocated few resources to research. NASA has tended to move toward fundamental research and has devoted less attention toward applied research, which would benefit the U.S. fisheries. Neither agency is devoting adequate attention to operational ocean systems. Nor is there sufficient support, notably by NOAA, to develop the understanding needed to better apply satellite remote sensing in fisheries. Inadequate consideration, for example, has been given to ground processing and data dissemination systems of satellite-derived products to fishermen and other users, including value-added companies, which could tailor satellite-derived data for specific fisheries needs.

The experience of our member companies suggests that the products currently available to the fishing industry are of limited use. These products are confined to sea surface temperature charts composited over a period of days. Ocean current and frontal dynamics which serve to concentrate fish are in a constant state of change. This variability requires real-time information. Composites produced over a period of days do not accurately reflect ocean conditions. Also, surface temperature technology depicts conditions within the first few centimeters of the ocean. Ocean frontal features that have been associated with better fishing, lose their surface signatures through solar heating and wind. The loss of the ability to detect these features on the surface happens well in advance of the loss of the general circulation. This circulation produces the changes in water density surfaces required to accumulate bait fish and subsequent concentrations of commercial species. Improved satellite coverage and technology is needed.

Another problem hindering fisheries is the failure to launch an ocean color sensor after the demise of the CZCS. There is a need for ocean color information. Concentrations of some species such as menhaden, are correlated with ocean color and not surface temperature. Yet, in spite of many false starts, there is no color sensor in space. The present plans are to include an ocean color imager, SeaWiFS, onboard the Landsat-6 satellite to be launched in the early 1990's. However, this plan has been on again, off again and presently is very much in jeopardy due to the uncertainty of federal commitment.

There is a very real danger that further delays will preclude the deployment of SeaWiFS on Landsat-6. The entire SeaWiFS mission represents about a 10 percent increase ($14 M) for the Landsat-6 mission, a very modest sum in comparison with its importance to U.S. fisheries and other ocean-related activities. Regardless of any new policies concerning the future of the Landsat program, it is important to have SeaWiFS on Landsat-6, or on an alternate satellite. We have grave concerns that another opportunity will be missed to launch a sensor which would provide some of the most useful information applicable to U.S. fisheries.

If the U.S. does not launch an ocean color scanner, the next opportunity for ocean color data is from the Japanese, who plan to fly an ocean color and temperature scanner in 1995, as part of a mission devoted largely to support of Japanese fisheries. The U.S. has developed and proven this technology, and has made excellent plans for continuation. A commitment on the part of the government for continuation is now in order.

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Sub-Committee On Oceanography
House Committee on Merchant Marine and Fisheries
House Annex 2, Room 575
Washington, D.C. 20515

April 16, 1989

Dear Sirs:

My comments here are based on my 12 years of experience using satellite data for fisheries utilization and management while working under several contracts for the United States National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), and the United Nations Food and Agricultural Organization. I was employed at the University of Miami, Rosenstiel School for Marine and Atmospheric Sciences during these projects. I presently own and operate a fishing forecasting service which provides strategic and tactical fishing and oceanographic information to approximately 100 United States based fishing companies. The information is derived primarily from satellite data and my company's principal product are fisheries oceanographic analyses (map and discussion) that are distributed daily, via telephone facsimile. In addition, my company sells a personal computer based portable satellite receiver - image display work station to U.S. and foreign fishing companies for ship board use. My company has been a leader in the use of satellite derived oceanographic data for fisheries applications, as well as, the use of personal computers for satellite data manipulation and analysis.

From a fisheries economic viewpoint I submit that the use of oceanographic data derived from U.S. meteorological satellites has been the critical factor for the increased operational efficiency and safety of U.S. fishing boats. This increased efficiency stems from the reduction of fuel, labor and other costs as consequence of finding productive ocean conditions more rapidly. Finding harvestable concentrations of fish efficiently results in a less costly consumer product within the U.S. and greater profits for fishermen. In addition, making use of U.S. based data and technology allows the U.S. fishing industry an increased competitive advantage by over foreign fishing companies and their products imported into the U.S., as well as, for exporting U.S. fish products to overseas markets. Reduction of fuel consumption lessons the overall U.S. dependance on foreign oil.

Your continued support for the U.S. space program overall is critical, as is the need for new space satellites for oceanography. Unfortunately, the present U.S. space program is not providing oceanographers and the fishing industry with the best data that is possible. Present space platforms and administrative polices are primarily dedicated to providing meteorological data for weather forecasting, while the fishing industry and other oceanographic uses are only a minor consideration. Present meteorological satellites only provide data for monitoring larger scale sea surface temperature features. My research, as part of a larger research effort, has shown that there is a need for new satellites that can provide information to the oceanographic community and the meteorological community. These new satellites should house multi-channel ocean color and infrared scanners, *in addition to other microwave sensors* that would be able to resolve important ocean features related to color and biological productivity that present instruments can not. The ocean color - infrared data would be utilized by the academic and corporate research community, fishing industry, and the Department of Defense, i.e., the Navy. These satellites must provide high resolution (1 mile or less) data with high rate area repeatability (twice a day or more).

To achieve the maximum benefits from such a dedicated oceanographic satellite the data must be immediately available to all users. This includes users from industry, academia, and U.S. governmental agencies (NASA, NOAA, Navy). It is clear to me and others in industry that the present mechanisms which satellite data are made available and distributed must be overhauled. Presently, only a privileged small group of people can afford to receive the highest resolution data immediately from the NOAA series satellites. Many people are denied immediate access to the high quality NOAA data, through sanctioned and unsanctioned data embargos, administrative red tape, and incompetent and selfish government employees. My company and others have been forced to develop satellite data processing systems to receive a lower quality data streams transmitted from space satellites operated by the United States and the Soviet Union. I think it is a sad day, when U.S. companies have to rely on Soviet data when we can not gain access to data that our tax dollars have paid for. Therefore, I think that administration of any new satellites should be by a joint venture of corporate, academic, and government interests.

Congressional support for ongoing and new satellite systems and programs must continue beyond sensor development and launch. Optimal use of satellite resources can only come from: 1) a well funded research and development program that; 2) includes effective technology transfer programs; 3) includes aid to small businesses who take a financial risk in introducing and using new technology and; 4) a central data archive.

In conclusion, your support is necessary so that U.S. industry and scientists remain at the forefront of the world community. Critical scientific, safety and defense questions can only be answered with new satellites systems that can: A) monitor small scale ocean conditions and large scale global climate changes; B) monitor oil spills and other environmental pollution; C) be used to further develop and manage our natural ocean resources; and D) be used by the military for fleet operations.

I thank you for this opportunity to provide this testimony.

Sincerely,

Mitchell A. Roffer, Ph.D.
President